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# THE CALENDARS OF SOUTHEAST ASIA. 1: INTRODUCTION

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**Abstract:** In this chapter we examine calendars in general and also give a condensed political history of the region. We then discuss the influences of Indian, Chinese, and Islamic astronomy in Southeast Asia. In subsequent papers in this series we will examine in detail the astronomy and calendars found in Burma (Myanmar), Thailand, Laos, Cambodia, Vietnam, Malaysia and Indonesia, and the inscriptions, manuscripts and horoscopes associated with them.

We have already written about most of these regions previously, but in this series of papers we will update our earlier publications and synthesize them in order to present a detailed coherent picture of the calendars of SE Asia.

**Keywords:** Calendars, Myanmar, Thailand, Laos, Cambodia, Vietnam, Malaysia, Indonesia, India, China, Islam

―The investigation of the transmission of mathematics and astronomy is one of the most powerful tools for the establishment of relations between different civilizations". (Neugebauer, 1952: 1).

## 1 WHAT IS A CALENDAR?

A calendar[1] is a device for measuring and organising time and is an integral part of everyday society and is often closely connected with religion and have been used from the earliest times to regulate agricultural and economic activities. The sky with its constellations of stars can serve as an anchor for a calendar. Many cultures in Southeast Asia and elsewhere used the heliacal rise of the Pleiades or of the constellation of Orion for this purpose, marking the beginning of the harvest year. The spring or autumn equinoxes or the summer or winter solstices have also been used in the same way, an example is the Indonesian *mangsa* calendar; and the Egyptians used the heliacal rising of Sirius. Again, the early Roman calendar started the year close to the spring equinox in March and we can still see in the names of the Western months, September, October, November and December that they were once months seven to ten in a lunar calendar starting the count with March. Calendars have with few exceptions a strong relation to astronomy.

The solar day is the natural unit of time for most calendars. One of the ideas of a calendar idea is to attach a unique identifying tag to each day, its date, as when specifying the year, month and day, although there are several other options to achieve the same goal—for example by adding redundant information like specifying the weekday.

In some cases, also the time of the day is specified as is done with the Indian *lagna* or rising sign of the zodiac. Solar days are structured in larger units or cycles like weeks, months and years. People of all ages have used different natural or artificial periodic cycles in order to construct their calendars. An early natural cycle, certainly used since the dawn of humanity, is the cycle of the phases of the Moon. This gives a system of easily manageable time blocks, the full phase cycle of 29 or 30 days, the synodic month and the time between the different lunar phases, about seven days that may be the origin of the 7-day week that is very ancient. The Islamic calendar is one such pure lunar calendar, the start of each lunar month being determined by the first visual observation of the New Moon crescent in the evening, with the year having 12 such lunar months where there is little or no need of any numerical calculation. Examples of more artificial calendar cycles with little connection with natural events are the 260-day *tzolkin* used by the Mayans based on subcycles of 13 and 20, and the 210-day Balinese *Pawukon* calendar.

Calendars can be divided into two types: astronomical calendars based on real events in the sky like the original Islamic calendar mentioned above and the Chinese calendar; and arithmetic calendars based on cycles and/or arithmetical rules although with relations to the celestial sky. Most of the calendars in Southeast Asia are of the latter type.

Different calendar schemes begin the solar day at different times. India has two canonical variants that are relevant here, the *Sūryasiddhānta* canon, in which the astronomical day begins at midnight, the *ārdharātrika* system, and

the *Aryabhāta* canon where it begins at sunrise, the *audayika* system. The civil day in the calendars of Southeast Asia normally begins at sunrise but the astronomical day begins at midnight. This in some cases creates an ambiguity in determining the day number and the name of the weekday, there can be different weekdays and day numbers if the time of the day is located between midnight and sunrise, depending on whether the astronomical or civil convention is used. In the Islamic calendar the civil day always begins at sunset.

Once agriculture became common, there was a need for calendars that were correlated with the seasons, i.e. with the Sun. Such a calendar is the Egyptian calendar having a year of 12 months of 30 days each and five extra days, in total 365 days, a rather crude approximation to the true solar year but later improved with an extra leap day. The Western Julian and Gregorian calendars are examples of solar calendars that follow the seasons quite accurately by using leap days although an implicit lunar calendar is still used to determine Easter and the ecclesial year. A happy compromise can be made by combining the solar and lunar calendar into a luni-solar calendar.

In luni-solar calendars there are four sequences of time that need to be synchronised: the progress of the Sun, the solar calendar, the lunar calendar, and the progress of the Moon. As a solar year is slightly more than 365 days, and a solar calendar contains an integral number of days, there is a need to insert leap days, resulting in a solar calendar year with 365 or 366 days. The Julian calendar, in use before CE 1582 (Common Era), intercalates a leap day every four years, in every year divisible by four, and approximates the solar year with an average of 365.25 days. The Gregorian calendar fine-tunes this by skipping the leap day every century year where the century is not divisible by four and has a solar year with 365.2425 days, a rather good approximation of the real tropical solar year with 365.2422 days.[2] The Indian luni-solar calendars in Southeast Asia use a sidereal solar year with 365.25875 days or in the later Burmese luni-solar calendar based on the modern *Sūryasiddhānta* with 365.25875648 days. Such solar years will be about 11 days longer than a lunar year with 12 synodic months with a mean length of about 29.5 days and giving a total of about 354 days. In order to synchronise the lunar and solar calendars, the usual procedure is to intercalate extra lunar months from time to time. Finally, in order to synchronise the lunar calendar with the Moon there may also be a need to intercalate extra days in the lunar calendar (Gislén, 2018). The intellectual task of solving the intercalation problem has generated a host of interesting calendar variants and calculation schemes (Reingold and Dershowitz, 2018) and often stimulated the science of mathematics.

The Babylonians originally had an astronomical lunar calendar with months, which, like the Islamic calendar, started with the first visual observation of the New Moon crescent. This automatically synchronised the lunar calendar with the Moon. The synchronisation with the Sun was done by requiring that the start of the lunar year should not deviate too far from the spring equinox, and if it did, an extra lunar month was inserted and there was not in this respect a need for a separate solar calendar. From around the fourth century before the Common era (BCE), the Babylonians were able to predict the appearance of the New Moon by calculation and also switched to a more rigid system with seven intercalary lunar months in 19 solar years, inserted at fixed years 3, 6, 8, 11, 14, 17 and 19 in the 19-year cycle and giving a total of 235 lunar months in each 19-year cycle. This Metonic cycle is quite accurate: 19 tropical years of 365.2422 days are almost equal to 235 synodical months of 29.53059 days, where $19 \times 365.2422 = 6939.6018$ days, and $235 \times 29.53059 = 6939.6886$ days. The cycle has its name from the Greek astronomer Meton who lived in the fifth century BCE but it was known much earlier to Babylonian and Chinese astronomers. This reckoning gives a good synchronisation between the Sun and the lunar calendar. A similar scheme was inherited and used in the Jewish calendar and in some ancient Greek calendars. The advantage of a fixed computational scheme is that it is possible to plan and predict future events like gatherings and celebrations and thus serves as an important administrative tool.

All the regions of Southeast Asia had some kind of luni-solar calendar from around the seventh century, brought from India by Buddhist monks. The exception is Vietnam which was heavily influenced by Chinese luni-solar calendars. Indonesia early adopted a calendar that was close to the original Indian *Sūryasiddhānta* calendar (Eade and Gislén, 2000) but with a slightly different intercalation pattern. Quite early, around the sixth and seventh century in the Common era, Islamic traders visited Indonesia, being interested in the profitable spice trade. In the thirteenth century, Islam was spreading in the area, starting with northern Sumatra and the Malay Peninsula and replacing Hinduism. Other Indonesian areas gradually adopted Islam and by the sixteenth century it was the dominant religion in Java. Bali was the last region to retain a Hindu majority. In CE 1633, Sultan Agung formally inaugurated the Islamic calendar in Java but it had a slightly modified intercalation scheme as compared with the original Islamic

calendar and was combined with the traditional five- and seven-week calendrical systems while retaining the Śaka era, CE 78. Burma, Laos, Thailand, and Cambodia, on the other hand retained calendars clearly inspired by India but with a more rigid way of intercalating months and days.

These calendars ceased to have official status in several mainland Southeast Asian states with the arrival of the European colonialism but are still used for cultural and religious festivals. The Gregorian calendar was adopted in Cambodia in 1863, in Burma 1885, and in Laos 1889. In 1888 it also became the official civil calendar in the independent Kingdom of Siam that today is Thailand and in 1954 the Gregorian calendar became the official civil calendar in Vietnam.

## 2 POLITICAL HISTORY

The political history of Southeast Asia is long and complicated. From early on, the Mainland was dominated by the Funan states, encompassing modern-day Cambodia, southern Vietnam, Laos and eastern Thailand, with different Hindu powers profiting from the trade between India and China. The maritime Southeast Asian trade was dominated by the powerful Srivijaya state. As its influence declined, the Khmer Empire expanded and experienced its golden age from the eleventh to the thirteenth century CE when it controlled the major part of the Mainland. In the east, in what is now central Vietnam, the Champā state ruled, and in the west from around CE 1050 the Pagan Kingdom in what is now Burma was on the rise. During the thirteenth century CE, the region experienced several Mongol invasions in Burma, Dai Viêt (present northern Vietnam) and Java that weakened or destroyed the established powers. The southern archipelago saw the rise of the Majapahiti Empire in eastern Java. This empire successively grew to control also the southern Malay Peninsula, Borneo, Sumatra, and Bali. Around CE 1200 the Thai state of Sukhothai in the north of present-day Thailand was created at the expense of the weakened Khmer Empire. Around CE 1350 the Thai states were united in the Ayutthaya Empire. At its peak it controlled the larger part of the Mainland, fighting frequent wars with the rival Khmer and the Burmese states. The Ayutthaya Kingdom lasted until about 1750 when it was destroyed by the Burmese. In the north, also aided by the decline of the Khmer Empire, the Lan Xang state rose in power and finally became what is now Laos. In maritime Southeast Asia, the Majapahiti state collapsed around CE 1500 and was replaced by Islamic sultanates in Java and on the Malay peninsula and finally most of what is present-day Indonesia was dominated by Islamic powers.

Dai Viêt was dominated by Chinese rule up to the middle of the tenth century. Until the French colonisation in CE 1858 it was, except for some shorter periods, independent and for much of the time ruled by different warlords and expanded southward. In 1471 the Vietnamese invaded and reduced the Champā state to a small enclave and many of its inhabitants fled to Cambodia.

Western influence started in the sixteenth century with the arrival of the Portuguese in Malacca. Throughout the seventeenth and eighteenth centuries the Dutch established the Dutch East Indies; the French Indochina; and the British Strait Settlements. By the nineteenth century all the countries in Southeast Asia were colonised except for Siam (Thailand). In World War II, Southeast Asia was invaded and occupied by the Japanese. After the war, Burma (Myanmar) became independent in 1948, Cambodia and Laos in 1953, Indonesia in 1945, Vietnam in 1976, and Malaysia in 1948.

Table 1: The Indian zodiacal signs.

| Solar Month | | English Translation | Associated Lunar Month | |
|---|---|---|---|---|
| Meṣa | मेष | Ram | Vaiśākha | वैशाख |
| Vṛṣabha | वृषभ | Bull | Jyeṣṭa | ज्येष्ठ |
| Mithuna | मिथुन | Twins | Āṣādha | अषाढ |
| Karka | कर्क | Crab | Śravaṇā | श्रवणा |
| Siṃha | सिंह | Lion | Bhādrapadā | भद्रपदा |
| Kanyā | कन्या | Virgin | Aśvina | आश्विन |
| Tulā | तुला | Balance | Kārttika | कार्त्तिक |
| Vṛścika | वृश्चिक | Scorpion | Mrgaśīrṣa | मृगशीर्ष |
| Dhanusa | धनुष | Bow | Pauṣa | पौष |
| Makara | मकर | Sea Monster | Maghā | मघा |
| Kumbha | कुम्भ | Water-carrier | Phālguna | फाल्गुन |
| Mīna | मीन | Fish | Caitra | चैत्र |

## 3 INDIAN, CHINESE AND ISLAMIC INFLUENCES

### 3.1 Indian Influences

The roots of astronomy in India are very ancient. Some concepts certainly were introduced already in Vedic times, and there are indications of ideas coming from Hellenistic and Persian astronomy from around the times of the beginning of the Common era, especially in astrology. The Indian zodiacal names are direct translations of the Greek ones (Table 1). Many Indian astronomical terms can be traced to Greece, like Sanskrit *kendra*, *lipta* from Greek *κέντρον*, *λεπτον*. Other influences may have come from Babylonia and China and certainly there are many independent Indian ideas. There is still an on-going and sometimes heated debate on the details of these roots. Indian astronomical ideas were transmitted to Southeast Asia and also to Nepal and China, and they influenced Muslim astronomers like al-Khwārizmī and al-Birūnī.

Most of the calendars in Southeast Asia, except the ones in Vietnam, are closely related to the original *Sūryasiddhānta* canon in India conceived around CE 500 by the mathematician-astronomer Aryabhāta (CE 476–550; Billard, 1971: 80, Mercier, 2012). This canon is different from the modern *Sūryasiddhānta* treated by Burgess (2000) which is a later improvement of the original canon. The modern *Sūryasiddhānta* uses updated values for the rotational periods and apogees of the Sun, the Moon, and the planets and a more involved model for the true longitudes. The backbone of the luni-solar calendar in the *Sūryasiddhānta* is a sidereal solar calendar, i.e. a calendar where the solar year is determined by the return of the Sun to the same location relative to the fixed stars, in contrast to the tropical year that is based on the return of the Sun to the vernal point, the crossing between the ecliptic and the celestial equator.

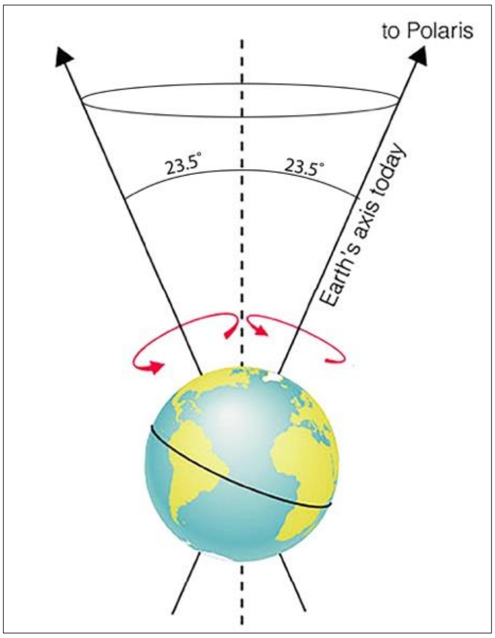



Figure 1: Precession of the equinoxes [diagram: Lars Gislén).

By the precession of the equinoxes, the vernal point is slowly receding westwards relative to the stars by about 1° in 72 years. This movement of the equinoxes is caused by the gravitational forces of the Sun and the Moon on the equatorial bulge of the Earth. These forces cause the rotational axis of the Earth to move like that of a spinning top on a table, tracing out a cone with an apex angle of close to 23.5° and with a period of about 26,000 years (Figure 1). Superimposed on this motion are much smaller deviations, the nutation, with shorter periodicity mainly due to the inclination of the lunar orbit relative to the ecliptic. These small deviations can be ignored in our context. The precession of the equinoxes was probably known already to the Babylonians but it was the Greek astronomer Hipparchus who around 130 BCE by his observations concluded that the rate of precession was about 1° per century. Ptolemy claims in the *Almagest* that he got precisely that value also from his observations (Toomer, 1984). The correction for precession from the time of Hipparchus, 266 years earlier, would then amount to 2° 40′. In reality the precession rate is about 1° in 72 years and the correction for precession should be 3° 40′, a difference of 1°, and indeed the longitudes of the stars in Ptolemy's star catalogue are in error by precisely this amount when compared with modern calculations. It is now (reluctantly) accepted that Ptolemy's star catalogue is a copy of an earlier, now lost, Hipparchean star catalogue that Ptolemy up-dated with his value of the precession although this conclusion has been hotly debated (e.g. see Grasshoff, 1990; Newton, 1977). When later Arabic and Persian astronomers measured the rate of the precession rate and found a larger value for it, they tried to explain this fact by inventing the erroneous hypothesis of the trepidation of the equinoxes, assuming that the equinoxes in addition to a constant motion also oscillated back and forth. The hypothesis of the trepidation of the equinoxes remained part of Medieval Western astronomy until the time of Kepler. In Indian astronomy the precession rate is described by a zig-zag function with a period of 3,600 years and an amplitude of 27°. When day length, shadows and parallax in solar eclipses are calculated it is necessary to use tropical ecliptic longitudes, i.e. sidereal longitudes corrected for precession.

The sidereal year is slightly longer than the tropical year, its current value being 365.25626 days, while the tropical year has 365.2422 days. The early Indian calendar that will be considered here, uses a sidereal year of 365.25875 days (Billard, 1971: 75), where the basis of this reckoning is the assumption that the Sun makes 4,320,000 circuits (*bhagaṇa*) around the Earth in 1,577,917,800 days, the *mahayuga*. The epoch of this calendar, the *Kaliyuga* era, is midnight at Ujjain on 18 February CE –3,101 (3102 BCE),[3] Julian Day 588465.5.[4] Ujjain is the prime meridian or Greenwich of India, situated at longitude 75.8° E and latitude 23.2° N in the state of Madhya Pradesh. At epoch the Sun, the Moon and the planets were all assumed to have mean longitude zero. In the early version of the Indian calendar, each solar month starts when the Sun's mean sidereal longitude reaches a multiple of 30°, i.e. when the mean Sun enters a new zodiacal sign. This aligns the solar calendar with the mean Sun and results in twelve solar months, each with the same length of 365.25875/12 = 30.43823 days. The entry of the mean Sun in a zodiacal sign can occur at

any time of the day but the civil solar month starts on the following sunrise.

The *Sūryasiddhānta* lunar calendar was in early times based on the mean synodic month. The lunar sidereal motion is expressed as the Moon making 57,753,336 sidereal circulations in 1,577,917,800 days. This means that relative to the Sun, the Moon makes 57,753,336 – 4,320,000 circulations, i.e. each circulation takes 1,577,917,800/(57,753,336 – 4,320,000) = 29.530587 days, the length of the mean synodic month. This is a very accurate value; the present current value is 29.530589 days. A synodic month starts when the Moon and the Sun have the same longitude, at New Moon, or in some parts of India when the Moon is opposite to the Sun, at Full Moon. The name of the lunar month is associated with the solar month in which the lunar month starts (see Table 1). As with the solar month the lunar month can start at any time of the day but the civil lunar month starts on the following sunrise. The fact that the mean synodic month is shorter than the mean solar month means that there will sometimes be two lunar months starting in the same solar month, i.e. a second New Moon at a time when the Sun is still in the same sign as at the previous New Moon. The first of these two months is then an intercalary month, *adhikamasa* but will otherwise have the same name as the second month. In this way there will be a lunar month intercalation when it is needed and the synchronisation between the solar and lunar calendars will be automatic.

Figure 2 illustrates the system of month intercalation. Lunar month 1 begins in solar month A and will get the lunar month name associated with solar month A. Likewise lunar month 2 will start in solar month B and get the corresponding name. However, lunar months 3 and 4 both begin in solar month C and will both get the name associated with C, the first of these lunar months with the name prefixed by the word *adhika*. Lunar month 5 starts in solar month D and will get the name associated with this month.

In Southeast Asia the system was changed, such that the extra month was confined to the first (in the Arakanese calendar) or fourth month (in the Makaranta, Thandeikta, and Thai calendars) of the lunar year.

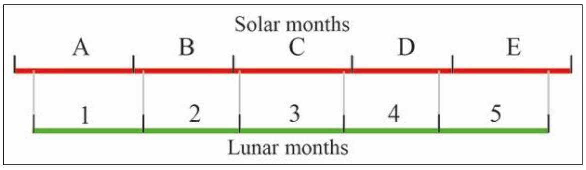



Figure 2: Month intercalation (diagram: Lars Gislén).

An important quantity in Indian astronomy is the *tithi,* or lunar day, a time interval being 1/30th of a synodic month, a concept found already in Babylonian astronomy, a *tithi* being the time it takes for the distance between the Sun and the Moon to increase by 12°. The *tithi* can also refer to the position of the Moon relative to the Sun in terms of these 12° intervals. The *tithis* are numbered from one to fifteen waxing (*śukla*), the fifteenth being Full Moon, *purṇima*, then from one to fifteen waning (*kṛṣṇa*), the last day being *amāvāsya*, New Moon (see Table 2). The lunar days in a lunar month are denoted by the number of the *tithi* in force at sunrise. As the mean *tithi* is shorter than a civil solar day, there will occasionally be a *tithi* that is not in force at sunrise of the morning of any day in the month. The *tithi* is then suppressed and that lunar month will have only 29 days. This procedure will align the lunar calendar with the (mean) Moon.

Later, true solar and lunar months and days were introduced in the Indian luni-solar calendar. The length of both the solar and lunar month then varied, making the intercalation system mathematically more complicated but still using the same principle for intercalation. One consequence of using true longitudes is that, very rarely, there is no lunar month starting in a solar month and then the corresponding lunar month is suppressed, *kṣayamasa*. Also, in some rare cases a *tithi* will be assigned to two solar days. In the modern Indian luni-solar calendar there are some amendments to the canonical parameters, the number of days in the modern *Sūryasiddhānta* in a *mahayuga* is for instance 1,577,917,828 resulting in a slightly longer sidereal year.

Table 2: *Tithi* and *karana* names.

| *Tithi* | *Karana* | *Tithi* | *Karana* | *Tithi* | *Karana* |
|---|---|---|---|---|---|
| 1: Pratipadā śukla | Kiṃstughna-Bava | 11: Ekasaśī śukla | Vaṇija-Viṣṭi | 21: Saṣṭhī kṛṣṇa | Gara-Vaṇija |
| 2: Dvitīya śukla | Vālava-Kaulava | 12: Dvādasī śukla | Bava-Vālava | 22: Saptamī kṛṣṇa | Viṣṭi-Bava |
| 3: Tṛtīya śukla | Taitila-Gara | 13: Trayodaśī śukla | Kaulava-Taitila | 23: Astamī kṛṣṇa | Vālava-Kaulava |
| 4: Caturthī śukla | Vaṇija-Viṣṭi | 14: Caturdaśī śukla | Gara-Vaṇija | 24: Navamī kṛṣṇa | Taitila-Gara |
| 5: Pañcamī śukla | Bava-Valava | 15: Purṇima | Viṣṭi-Bava | 25: Dasamī kṛṣṇa | Vaṇija-Viṣṭi |
| 6: Saṣṭhī śukla | Kaulava-Taitila | 16: Pratipada kṛṣṇa | Vālava-Kaulava | 26: Ekasaśī kṛṣṇa | Bava-Vālava |
| 7: Saptamī śukla | Gara-Vaṇija | 17: Dvitīya kṛṣṇa | Taitila-Gara | 27: Dvādaśī kṛṣṇa | Kaulava-Taitila |
| 8: Astamī śukla | Viṣṭi-Bava | 18: Tṛtīya kṛṣṇa | Vaṇija-Viṣṭi | 28: Trayodaśī kṛṣṇa | Gara-Vaṇija |
| 9: Navamī śukla | Vālava-Kaulava | 19: Caturthī kṛṣṇa | Bava-Vālava | 29: Caturdaśī kṛṣṇa | Viṣṭi-Śakuni |
| 10: Dasamī śukla | Taitila-Gara | 20: Pañcamī kṛṣṇa | Kaulava-Taitila | 30: Amāvāsya | Nāga-Catuṣpada |

Table 3: *Naksatra* names.

| *Nakṣatra* | | |
|---|---|---|
| 1: Aśvinī | 10: Maghā | 19: Mūla |
| 2: Bharaṇī | 11: Purvaphalgunī | 20: Purvāṣaḍhā |
| 3: Kṛttikā | 12: Uttaraphalugī | 21: Uttarāṣaḍha |
| 4: Rohiṇī | 13: Hasta | 22: Śravaṇā |
| 5: Mṛgaśiras | 14: Citrā | 23: Daniṣṭha |
| 6: Ardrā | 15: Svāti | 24: Śatabiṣaj |
| 7: Punarvasū | 16: Viśākhā | 25: Purvabhadrapadrā |
| 8: Puṣya | 17: Anurādhā | 26: Uttarabhadrapadrā |
| 9: Āśleṣā | 18: Jyeṣṭhā | 27: Revatī |

Much of the astronomical Indian Sanskrit or Pali technical terminology has passed over to the Southeast Asian astronomy, the Indian *ahar-gaṇa*,[5] the number of elapsed days from the epoch, for instance, becomes *horakhun* in Thailand and Laos and *haragon/tawana* in Burma. The Indian origin of the Southeast Asian names of the solar and lunar months can often easily be recognised. The terms *rasi*, *angsa*, and *lipta* for zodiacal signs, degrees, and minutes of arc are Indian heritage (Gislén and Eade, 2020).

Also inherited from India in Southeast Asia are the concepts of *tithi*, *nakṣatra*, and *yoga*. The *nakṣatra* gives the position of the Moon relative to the stars, the ecliptic now being divided into 27 parts, each spanning 13° 20′. This agrees approximately with the *Sūryasiddhānta* sidereal period of the Moon 1,577,917,800 / 57,753,336 = 27.32167 days. Finally, the *yoga* is an artificial construction, being the sum of the longitudes of the Sun and the Moon, used in astrology and with the same division into 27 parts as the for the *nakṣatra*. The Thai term for the *nakṣatra* is *rœk* and the Burmese term is *nekkhat*. The Indonesian records use the Indian names for the *nakṣatras*, and *yogas* (see Tables 3 and 4). Each *tithi* is further divided into two *karanas* (see Table 2). Other examples of Indian influence are the division of the day (24 hours) into 60 *nadi,* Thai *nathi*, Burmese *nayi*, each *nadi* being subdivided into 60 *vinadi/ vinathi/bizana*, and the concept of *lagna*, the ascendant or the rising sign of the zodiac.

The *Sūryasiddhānta* canon also contains parameters and algorithms for the calculation of the sidereal longitudes of the planets, for the lunar node (Rahu*)* and apogee and for a fictive body, Ketu, that in Southeast Asian astronomy orbits the sky with a speed ten times that of Rahu and in the same retrograde direction. These computational schemes are taken over by several of the Southeast Asian calendars, albeit with somewhat simplified parameters.

Table 4: *Yoga* names.

| *Yogas* | | |
|---|---|---|
| 1: Viṣkamba | 10: Gaṇḍa | 19: Parigha |
| 2: Prīti | 11: Vṛddhi | 20: Śiva |
| 3: Āyuṣmat | 12: Dhruva | 21: Siddha |
| 4: Saubhāgya | 13: Vyāghāta | 22: Sādhya |
| 5: Śobhana | 14: Harṣaṇa | 23: Śubha |
| 6: Atigaṇḍa | 15: Vajra | 24: Śukla |
| 7: Sukarman | 16: Siddhi | 25: Brahman |
| 8: Dhṛti | 17: Vyatipāta | 26: Indra |
| 9: Sūla | 18: Varīyas | 27: Vaidhṛiti |

Both the Burmese and Thai calendars use a period of 800 years containing 292,207 days for the Sun. This is nothing but the *Sūrya-siddhānta* canonical numbers 4,320,000 and 1,577,917,800 divided by 5,400 and is an obvious heritage from India. Most of the Indian-influenced calendars in Southeast Asia use the notation of elapsed years, the first year of the era being zero.

## 3.2 Chinese Influences

The Chinese calendar is very old, having roots back in the fourteenth century BCE and there have been more than 50 calendar reforms since then (Reingold and Dershowitz, 2018). It is a luni-solar calendar based on astronomical events, not on arithmetical rules, involving the longitudes of the Sun and the Moon. This calendar has had a strong influence on those of Korea, Japan and Vietnam and also to some extent on the Tibetan calendar. Since CE 619 true longitudes have been used for the Moon and since CE 1645 also for the Sun. The version described below is the CE 1645 implementation taken from Reingold and Dershowitz (ibid.).

The Chinese year consists of lunar months where the arrangement of these months depends on the position of the Sun in the zodiac. The Chinese zodiac is divided into 24 solar terms each corresponding to a 15°-segments of which there are 12 major solar terms starting at the beginning of the zodiacal signs and 12 minor terms starting at the middle of the signs. A solar month then consists of one major and one minor term. The dates and times for these solar terms depend on when the Sun enters the respective terms which in turn depends on the geographical longitude adopted for the calendar. Before CE 1929 the Chinese calendar used the meridian of Beijing as the prime meridian, after that the meridian for Chinese standard time, UTC + 8 hours has been used. The solar term corresponding to the winter solstice determines the intercalation of lunar months in the calendar. Between two winter solstices there can be either twelve or thirteen new Moons, in the latter case there will be an intercalary month, otherwise the year will be a normal one with twelve lunar months. Chinese lunar months begin at New Moon on midnight of the day at the prime meridian. The arrangement of the lunar months is determined by the rule that the winter solstice always occurs during the eleventh month. There is a second rule for an intercalary year that determines that the intercalary lunar month

should be the first month that is wholly within a solar month. An equivalent formulation of the rule is that if two lunar months start in the same solar month, the first one will be intercalary. In this formulation it is identical to the rule for an intercalary month in the Indian calendar. As the calendar is astronomical it is automatically synchronised with the Sun and the Moon and the winter solstice rule will align the solar and lunar calendars. In China the required calculations were made by the imperial astronomers. There were many reforms of the calendar, each new dynasty changing the intercalary rules in order to be seen to make the calendar more perfect.

The Vietnamese calendars have many similarities with the Chinese calendar but with some substantial differences. The other calendars in Southeast Asia have less Chinese influence except in the use of sexagesimal cycles. In Northern Thailand sexagesimal cycles are used for days and years that show a great similarity to the Chinese sexagesimal year cycle built on a combination of a 10- and a 12-year cycle. The year names in the 12-year cycle are the same as the Chinese ones except for the last one that is sometimes ‗Elephant‘ instead of ‗Pig‘ (Davies) and in Vietnam ‗Rabbit‘ is changed to ‗Cat‘. It seems that these names, originally Chinese, were borrowed from Old Vietnamese into the Khmer language during the pre-Angkor era and then spread to the Thai region (Ferlus, 2013). However, the Thai decimal cycle names differ from the corresponding Chinese ones and seem to have a separate origin. The sexagesimal day cycle in Northern Thailand is also combined with the seven-day week cycle to create a 420-day cycle. This is a very valuable dating complement in cases where calendrical records are accompanied by sexagesimal information. In Burma there is also a 12-year cycle but there the years take the names of the Indian lunar months.

### 3.3 Islamic Influences

The original Islamic calendar is a purely observational and strictly lunar calendar. The start of each month is determined by the first sighting in the evening of the New Moon crescent. The year contains twelve lunar months. There is no cyclical intercalation of months or days. The mean year length is a little more than 354 days which means that it is not fixed in relation to the seasons and the solar year but migrates through the solar year over a period of about 32 years. The epoch of the calendar is CE 16 July 622, the exit from Mecca by the prophet Mohammad.

The observer-based foundation of the calendar presented some problems when Islam and the calendar was introduced in regions with a larger time difference from the Middle East and thus created observational differences in the start of the months and in many places a modified arithmetic Islamic calendar was used. This calendar has a fixed set of twelve months with alternate 30 and 29 days and a 30-year cycle for the intercalation of an extra day in eleven years, added to the last month. The intercalary years are the cyclic years 2, 5, 7, 10, 13, 16, 18, 21, 24, 26, and 29 (Reingold and Dershowitz, 2018). Some Muslims use the cyclic year 15 instead of 16. The Islamic calendars adopted in the Southeast Asia archipelago introduced still more variants trying to adapt the calendar to the traditional cyclic 7- and 5-week patterns of the region.

## 4 CONCLUDING REMARKS

Calendars are an interesting feature of Southeast Asian nations not least because they reveal the influences of the flanking powers, China and India, but also display their own distinctive local innovations. Calendars are intimately connected with religious and other festivals and commemorations as well as with agriculture and are often defended fiercely as part of the cultural tradition against foreign influence and are sometimes used to express dominance. The calendar reform in Europe in 1582, introduced by Pope Gregory XIII to replace the Julian calendar with the Gregorian one, was considered as a kind of Papist plot by the Protestant countries and it took about two centuries to be accepted by them.

The heritage from India in the Burmese, Thai and Maritime Southeast Asia early calendars is substantial. However, the astronomy and calendar schemes in India have a theoretical astronomical basis while schemes in Southeast Asia are built on a set of arithmetic computational rules with little explanation. Chinese influence on the calendars of Southeast Asia is generally weak with the exception of the Vietnamese calendar. Elements of a Chinese sexagesimal cyclic reckoning for years and days can be seen in northern Thai and Laos. The states in the Southeast Asian archipelago successively adopted a modified version of the Islamic calendar starting around the fifteenth century in the Common era.

## 5 NOTES

1. For specialist astronomical terms used in this paper see the Glossary in Section 7.2.
2. The Persian arithmetic calendar with an intricate leap year pattern following a cycle of 2820 years is at present the best emulation of the tropical year (Reingold) and is asserted to have an error of only a couple of minutes in 2820 years.

3. There are two ways of expressing years before the Common (or Christian) Era. Historians use the system that the years before CE 1 come 1 BCE, 2 BCE and so on. The astronomical system uses negative years; the years before CE 1 are CE 0, CE –1, CE –2 and so on. Thus, mathematically *n* BCE = – (*n* – 1) CE.
4. This epoch appears in the Alfonsine Tables as ‗Diluvio', i.e. the Flood. Meanwhile, for more information about Julian days see Section 7.1, below.
5. The transcription of the many technical terms in Sanskrit, Pali, Burmese, Thai, and Khmer presents some problems. The principle, although not strictly adhered to, has been to write such terms in italics and with diacritics the first time they appear but in plain font and without diacritics afterwards. In a few cases also Burmese and Thai scripts have been used. In most cases the Sanskrit/Pali terms has been retained.

## 6 REFERENCES


Billard, R., 1971. *L'Astronomie Indienne.* Paris, École Française d'Extrème-Orient.

Burgess, E., 2000. *The Sûrya Siddhânta*, Motolal Banarsidass, Dehli. Reprint.

Davies, R., 1976. The northern Thai calendar and its uses. *Anthropos*, 71, 3–32.

Eade, J.C., and Gislén, L., 2000. *Early Javanese Inscriptions. A New Dating Method*. Leiden, Brill.

Ferlus, M., 2013. The sexagesimal cycle from China to Southeast Asia. 23rd Annual Conference of the SoutheastAsian Linguistics Society, Bangkok, Thailand.

Gislén, L., 2018. On lunisolar calendars and intercalation schemes in Southeast Asia. *Journal of Astronomical History and Heritage*, 21, 2–6.

Gislén, L., and Eade, J.C., 2020. The influence of India on Southeast Asian astronomy: of calendars and calculations. In Orchiston, W., and Vahia, M. (eds.). *Exploring the History of Southeast Asian Astronomy: A Review of Current Projects and Future Prospects and Possibilities*. Cham (Switzerland), Springer.

Grasshoff, G., 1990. *The History of Ptolemy's Star Catalogue.* New York, Springer (Studies in the History of Mathematics and Physical Sciences, 14).

Meeus, J., 1998. *Astronomical Algorithms*. Richmond, Willmann-Bell.

Mercier, R., 2012. The reality of Indian astronomy. In Delire, J.M. (ed.), *Astronomy and Mathematics in Ancient India*. Leuven, Peeters (Lettres Orientales et Classiques, 17). Pp. 15–51.

Neugebauer, O., 1952. *The Exact Sciences in Antiquity*. Princeton, Princeton University Press.

Newton, R.R., 1977. *The Crime of Claudius Ptolemy*. Baltimore, Johns Hopkins University.

Reingold, E., and Dershowitz, N., 2018. *Calendrical Calculations*. Cambridge, Cambridge University Press.

Toomer, G.J., 1984. *Ptolemy's Almagest*. London, Duckworth.


## 7 APPENDICES

### 7.1 The Julian Day and the Equation of Time

The Julian Day is a tool used in chronology in order to uniquely tag a historical event. It was introduced by the French scholar Joseph Scalinger (1540–1609). Julian Days are counted starting with zero from the epoch at Universal Time (UT) 12 hours, 1 January 4713 BCE in the proleptic Julian calendar. The epoch is sufficiently far back in time for any meaningful historical record to have a positive Julian Day. Any date in any calendar can be converted to a Julian Day, something that is very useful in conversions between different calendars. For instance, the Gregorian calendar date UT 15:11, 26 March 2019, corresponds to Julian Day 2458569.127 where the fraction gives the time of the day counted from noon.

The time of the day today is given as standard mean solar time referred to a standard meridian and is the time shown by clocks. It is based on a fictitious mean Sun moving along the celestial equation with uniform speed. Mean noon is defined as the time when the fictitious Suncrosses a selected standard meridian where the Earth is divided into a number of standard time zones each with its standard meridian. However, the time used in civil practice until the middle of the nineteenth century was apparent local solar time where noon is defined as the time when the true Sun crosses the local meridian. The true Sun differs in two ways from the fictitious Sun. It moves along the ecliptic that is inclined to the celestial equator by an angle of about 23.5°, the obliquity. Secondly, because of the ellipticity of the orbit of the Earth, the movement of the Sun in the ecliptic is not uniform but varies during the year being fastest in January and slowest in July. The reason for using apparent local solar time is that in an epoch where mechanical clocks were rare, not very reliable or non-existent, one of the few ways to setting time was using the local meridian passage of the real Sun. The records of Southeast Asia in general are based on local apparent solar time. This was also the practice in Western astronomy until the end of the seventeenth century. Although in most cases the difference between apparent and mean solar time can be ignored, it can sometimes be critical for the interpretation of a record for example when time is referred to true sunrise.

The difference between apparent solar time and mean solar time is called *the equation of time*. Before CE 1833 it was standard to use a definition of the equation of time with the opposite sign: mean solar time minus apparent solar time. The equation of time is a function of the day of the year and has a variation of about ±15 minutes. It also has a slow secular variation that

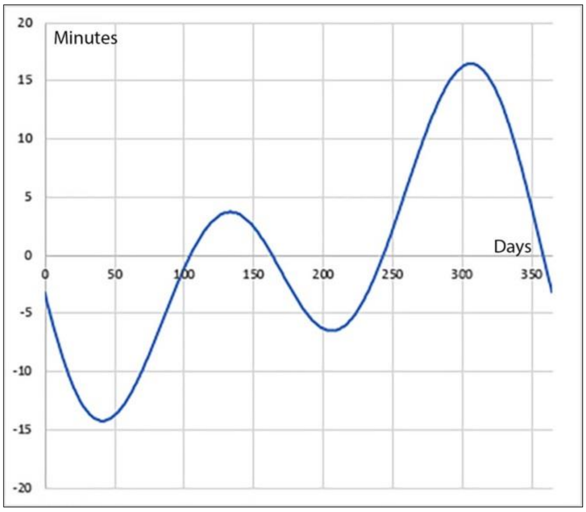



Figure 3: The equation of time (after Meeus, 1998).

can be neglected in this context. Figure 3 shows a graph with the current equation of time as a function of day of the year.

## 7.2 Glossary

*ahargaṇa* The number of elapsed days since the epoch.

*angsa* An Indian term for one zodiacal degree of arc.

*Aryabhāta* Famous Hindu astronomer and mathematician who lived CE 476–550. He is the author of two important Indian canons: the *Sūryasiddhānta* and the *Aryabhātiya*.

*Ayutthaya Kingdom* A Siamese kingdom that existed from CE 1350 to 1767. The court of King Narai (1656–1688) had strong links with that of King Louis XIV of France.

*Champa State* A State extending along the coast of what is today central and southern Vietnam from approximately the second century CE until being finally absorbed and annexed by the Vietnamese Emperor Minh Mang in CE 1832 .

*CE, Christian era* The common era used in the Western Word. Its epoch is Julian Day 1721423.5.

*Đại Việt* The name of Vietnam for the periods CE 1054–1400 and CE 1428–1804.

*equation of time* The correction to be applied to mean solar time to get apparent solar time.

*equinox* The time when the Sun passes the equator. On the equinox the day and night are equally long.

*Gregorian calendar* The present calendar in most of the non-Islamic world and introduced in CE 1582 by Pope Gregory XIII. It is a solar calendar with normal years of 365 days and leap years with 366 days. In intercalates a leap day when the year is divisible by 4 except for century year where the century year is not divisible by 4. The mean length of this year is 365.2425 days. The epoch is CE 1 January 1.

*heliacal rising* The first day when the star (after a period when it was invisible) rises in the morning before the Sun and the Sun is still far enough below the eastern horizon to make it briefly visible in the morning twilight.

*Islamic calendar* A purely lunar calendar with twelve lunar months, each month beginning with the first sighting of the New Moon crescent in the evening. The epoch of the calendar, Hidjra or Hegira is CE 2 July 622 (Julian). Often used is the tabular Islamic calendar that has normal years of 354 days with 12 months with alternating lengths of 30 and 29 days and leap years with the last month having an intercalary day. The intercalation is governed by having 19 leap years in 30 years governed by a fixed sequence.

*Julian calendar* The Western calendar used before the introduction of the *Gregorian calendar*. It has a normal year with 365 days and leap years with 366 days, leap years being years that are divisible by 4. The mean length of the year is 365.25 days. The epoch is the same as for the Gregorian calendar, CE 1 January 1.

*Julian Day* A quantity, not having any relation with the Julian calendar, used by calendarists in order to have a unique number for each day. The epoch is noon 1 January 4713 BCE when the Julian Day number is 0. The epoch is sufficiently remote for historical dates to have a positive Julian Day number. A Julian Day starts at noon. It is a very convenient tool when studying relations between different calendars.

*Kaliyuga epoch* An epoch is used in Indian astronomy and is 18 February 3202 BCE. In the *Sūryasiddhānta* canon it is counted from midnight, in the *Aryabhātiya* canon from sunrise or 6 a.m.

Ketu An artificial celestial body in Southeast Asian astronomy moving with ten times the speed of Rahu and with only astrological significance. In Indian astronomy it is normally the descending node of the Moon.

*Khmer Empire* Conventionally the epoch of the Khmer Empire is dated CE 802. At its height it controlled the major part of the SE Asian Mainland. The Empire ended with the fall of Angkor in the fifteenth century.

*kṣayamasa* An Indian term for the suppression of a lunar month, something that can happen when true longitudes of the Sun and the Moon are used in the Indian calendar.

*Lan Xang* This was a Lao Kingdom that existed from CE 1354 to 1707. It was one of the largest kingdoms in SE Asia and the precursor of present-day Laos.

*lipta* Indian term for minutes of arc. Of Greek origin, $\lambda\varepsilon\pi\tau o\nu$.

*mahayuga* A time period used in Indian astronomy. It is a period of 4,320,000 solar years, in the *Sūryasiddhānta* canon consisting of 1,577,917,800 days, in the *Aryabhātiya* canon of 1,577,917,500, and in the modern *Sūryasiddhānta* canon of 1,577,917,828 days.

*Majapahiti Empire* A thalassocracy based on the island of Java that existed from CE 1293 to about 1500. During its height it extended from Sumatra to New Guinea.

*mangsa* An Indonesian agricultural solar calendar.

*Metonic cycle* A 19-year intercalation cycle for lunar months, used already by the Babylonians but being named after the Greek astronomer Meton who lived in the fifth century BCE.

*nadi* An Indian time measure with 60 *nadi* in a day and night. In Thai it is *nathi* and in Burmese *nayi*. It corresponds to 24 minutes.

*nakṣatra* A measure of the Moon's longitude where the zodiac is divided into 27 parts, each covering 13° 20′. In Thai it is called *rœk* and in Burmese *nekkhat*.

*Pagan Kingdom* The first kingdom to unify the regions that would later be the present-day Burma. From around the ninth century it expanded from settlements at Pagan. At the end of CE 1200 it was subject to several Mongol invasions.

*Pawukon* A Balinese cyclic calendar based on a combination of periods with one-, two-, three-,…, and ten-day ‗weeks' generating a repeating 210-day period.

*precession of the equinoxes* Due to the gravitational influence of the Sun and the Moon on the equatorial bulge of the Earth, the rotation axis of the Earth will trace out a cone similar to that of a spinning top on a table. This will cause the vernal equinox of the ecliptic to move slowly backwards along the celestial equator.

*precession rate* This is the rate of change in tropical longitudes due to the precession of the equinoxes, about 1° in 72 years.

Rahu The entity known in the West as the ‗Dragon's Head'. The plane of the Moon's orbit is inclined to the Earth by about 5°. From this it follows that there are two points, opposite each other: one where the Moon passes from having a southern or negative latitude to having a northern and positive latitude (the ‗Head'); and one where it passes from north to south (the ‗Tail'). These points are called the lunar nodes, respectively the ascending and the descending node, and they rotate slowly in a direction opposite to the direction pursued by the planets; i.e., the nodes have a decreasing longitude, not an increasing one. In SE Asian astronomy Rahu is considered a separate planet.

*rasi* An Indian term corresponding to the Western zodiacal sign.

*sexagenary cycle* A cycle generated by combining a ten-year cycle with a twelve-year one. In SE Asia it is generated by combining items with the same parity (odd-odd or even-even). It is similar and in some respects identical with the corresponding Chinese sexagenary cycle, the names of the years in the twelve-year cycle are identical to the Chinese ones. In the early Thai calendar, it is commonly used for both days and years, in Burma only for years in the twelve-year cycle and using the names of the Indian lunar months.

*sidereal year* A solar year defined by the time for the Sun to reach the same point relative to the stars. This is in contrast to the *tropical year* which uses the time for the Sun to return to vernal equinox. Due to the precession of the equinoxes these two years will be slight different in length. SE Asian astronomy is based on the sidereal solar year. The original *Sūryasiddhānta* sidereal year has 365.25875 days, for the modern *Sūryasiddhānta* has 365.2587648 days. The present modern value is 365.256363 days.

*Srivijaya* A city-state based in Sumatra and dominating the Indonesian archipelago between the seventh and eleventh centuries CE. In the thirteenth century it collapsed, mainly due to the expansion of the *Majapahiti Empire*.

*Sukhothai* A Thai state that grew out of several smaller states when the influence of the Khmer Empire declined. At the end of CE 1200 it controlled most of what is today Thailand. After that it rapidly decayed into Lao states in the north, Mon states in the west, and finally in CE 1378 the Ayutthaya Kingdom conquered the remains.

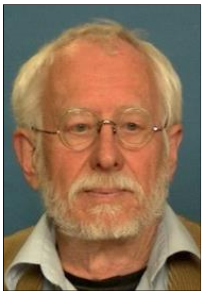
*Sūryasiddhānta* Indian canons. There are two canons with the same name. The original *Sūryasiddhānta* or here simply the *Sūryasiddhānta* was conceived by the Hindu astronomer Aryabhata around CE 500, while the modern *Sūryasiddhānta*, treated by Burgess, is an updated version of the original and dates from around CE 1200.

*synodic month* The time for the Moon to return to the same position relative to the Sun. It has a mean value of about 29.5 days.

*tithi* Originally a time unit being a lunar day or 1/30$^{th}$ of a synodic month, in SE Asian astronomy being 692/703 of a solar day. It can also refer to the lunar day number in a month and also the relative position of the Moon relative to the Sun, the possible 360° divided into 30 *tithis*, each one covering 12°. This unit of time was used already by the Babylonians.

*trepidation of the equinoxes* A concept invented by Medieval astronomers to explain the observed change in celestial longitude of the stars as compared with those in Ptolemy's start catalogue in Almagest. It assumes that the equinoxes on top of a constant precession rate also have an oscillating movement back and forth. It was part of Western astronomy up to the time of Kepler. The Indian version assumes a zig-zag motion with an amplitude of 27°and a period of 7200 years.

*tropical year* The time for the Sun to return to the vernal equinox. The current mean length of the tropical year is 365.24219 days.



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# THE CALENDARS OF SOUTHEAST ASIA. 2: BURMA, THAILAND, LAOS AND CAMBODIA

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**Abstract:** In this paper we investigate three Burmese calendars: the Arakanese, Makaranta and Thandeikta calendars. It is shown that the lunar calendar of the two first ones imply a tropical solar year, something that puts the lunar calendar out of phase with the sidereal solar calendar used and possibly indicates a Hellenistic origin. We then examine the calendars of Thailand, Laos and Cambodia, which superficially are similar to the Burmese calendars but have a completely different system of intercalation (Gislén, 2018; Ôhashi, 2006). Because Thailand, Laos and Cambodia have virtually the same luni-solar calendars, the Thai calendar is examined as a typical example.

**Keywords:** History of astronomy, calendars, Burma, Myanmar

## 1 BURMA (MYANMAR)

### 1.1 The Burmese Calendars

The Burmese luni-solar calendars (Htoon-Chan, 1918; Irwin, 1909) have a clear Indian origin but with some very important differences.[1] The calendrical schemes use mean quantities for the Sun and the Moon but for the astronomical calculations use true longitudes are used. The epoch of the original calendars is CE 22 March 638 and they generally count in elapsed years, the first year being year 0. The parameters of the original Burmese solar calendar are the original *Sūryasiddhānta* parameters[2] but scaled down by a factor of 5400, giving the Sun 292207 days in 800 year and a sidereal year of 29207/800 = 365.25875 days. The lunar calendar is based on the fact that 703 *tithis* (lunar days or 1/30$^{th}$ of a synodic month) correspond to 692 solar days. This gives a synodic lunar month of (30 × 692)/703 = 29.530583 days, an excellent approximation of the true synodic month.

The original Burmese calendars used a Metonic intercalation scheme for the lunar months, having 7 intercalary months in 19 years, an intercalary year having 13 lunar months instead of 12 months. The years with month intercalation are number 2, 5, 7, 10, 13, 15, and 18 in the 19-year cycle where the number in the cycle is calculated by the year modulus nineteen. This gives 19 × 12 + 7 = 235 lunar months in 19 years. Each lunar month contains exactly 30 *tithis,* thus in the 19-year cycle there are 235 × 30 = 7050 *tithis*. The number of solar days will then be (7050 × 692)/703 = 6939.687055 days. The mean solar year will have 6939.687055/19 = 365.24667 days. This is a tropical solar year equal to Hipparchus' tropical year of 365 + ¼ – 1/300 days, something that could indicate a Hellenistic influence. As will be seen below, this year length causes problems when combined with the sidereal year and could be an indication that the lunar and solar calendars were introduced in Burma at different times.

The lunar calendar has a normal year of 12 lunar months with alternating 29 and 30 days, in total 354 days. The names and lengths of the Burmese months (in days) are given in Table 1.

Table 1: Burmese months.

| Name | Days |
|---|---|
| *Tagu* (တန်ခူး) | 29 |
| *Kason* (ကဆုန် ) | 30 |
| *Nayon* (နယုန်) | 29/30 |
| *Waso* (ဝါဆို) | 30 |
| *Wagaung* (ဝါခေါင်) | 29 |
| *Tawthalin* (တော်သလင်း) | 30 |
| *Thadingyut* (သီတင်းကျွတ်) | 29 |
| *Tazaugmon* (တန်ဆောင်မုန်း) | 30 |
| *Nadaw* (နတ်တော်) | 29 |
| *Pyatho* (ပြာသို) | 30 |
| *Tabodwe* (တပို့တွဲ) | 29 |
| *Tabaung* (တပေါင်း) | 30 |

There are two variants of the early Burmese calendar: the Arakanese and the Makaranta. Both have an intercalary month with 30 days. The Arakanese calendar inserts this after the first month, *Tagu*, while the Makaranta inserts it after the fourth month, *Waso*. With 7 intercalary years in 19 years there are (354 × 19) + (7 × 30) = 6936 days. In order to have a calendar that keeps pace with the mean Moon an additional 6939.687055 – 6936 = 3.687055 days are needed in each 19-year cycle. This is done by the intercalation of extra days. In order to determine

where to insert these days there is a canonical scheme as introduced in the next section.

## 1.2 Day Intercalation

In the Burmese calendars an intercalary day can only be inserted in a year that also has an intercalary month. The intercalary day is added to the end of the third month, *Nayon*, which will then have 30 days. There will then be three kinds of year, normal years with 354 days, years with an intercalary month and 384 days (*wan-ngè-tat*), and years with both an intercalary month and an intercalary day and 385 days (*wan-gyi-tat*). To determine which years will have an intercalary day there is a quantity called the *avoman* that essentially is a measure of the excess of tithis relative to the solar days. The Makaranta calendar uses the *avoman* of the second *Waso* Full Moon (2WFM) as an indicator of when to intercalate a day. The scheme to compute the 2WFM *avoman* for any year with an intercalary month is as follows:

1) Take the number of elapsed years and multiply by 12 in order to get the number of lunar months.
2) Add 4, the number of elapsed months up to the second *Waso*, to get the total number of elapsed ordinary months, *m*.
3) Compute the number of intercalary months: $(m\cdot\times 7)/(12 \times 19) = (m \times 7)/228$. This implements the condition that there be seven intercalary months in nineteen years.
4) Add the number of intercalary months to the number of ordinary months to get the total number of elapsed months.
5) Convert the total number of lunar months to *tithis* by multiplying by 30.
6) Add the number of *tithis* elapsed up to the Second *Waso* Full Moon, i.e. 14, to get the total number of elapsed *tithis*, *t*.
7) Compute the *avoman* by the formula $(t \times 11 + 650) \bmod 703$.[3]

If the result is 0 it is replaced by 703. The number 650 is an epoch constant, the *tithi* excess at the epoch being 650/703.

Example: Compute the 2WFM *avoman* for the year 1242 in the Burmese era which had an intercalary month, number 7 in the 19-year cycle:

$1242 \times 12 + 4 = 14908$
$(14908 \times 7)/228 = 457$
Total elapsed months $14908 + 457 = 15365$
Elapsed *tithis* $(15365 \times 30) + 14 = 460964$
$(460964 \times 11 + 650) \bmod 703 = 515$, the 2WFM *avoman*.

Once the 2WFM *avoman* has been calculated for one of the intercalary years in the Metonic sequence it is easy to compute the 2WFM *avoman* for any subsequent intercalary year in the sequence by adding one of two numbers: 517 or 259, both modulus 703. The interval between two years in the intercalary sequence can either be two or three years. In a two-year interval there are two normal years with twelve months plus one intercalary month. Thus, $2 \times 12 + 1 = 25$ months and $25 \times 30$ *tithis* = 750 *tithis*. The excess $(750 \times 11) \bmod 703 = 517$ is the *avoman* change. As we consider a difference, the epoch constant will cancel.

In a three-year interval there are $3 \times 12 + 1 = 37$ months, where $37 \times 30$ *tithis* = 1110 *tithis*, and the excess $(1110 \times 11) \bmod 703 = 259$ is the *avoman* change.

The rule for inserting an intercalary day is this: if the 2WFM *avoman* of the intercalary year is larger than the previous 2WFM *avoman,* there will be an intercalary day. If you take the case of a two-year interval it is easy to see that this statement is equivalent to saying that the previous 2WFM *avoman* lies in the interval [1, 186]. If you add 517 to any number in this interval the result will be less than 703 and thus larger, if it is outside this interval, the sum will be larger than 703 and by the modulus condition will be reduced by 703 and thus then be smaller than the original number. In the same way for a three-year interval, if the previous 2WFM *avoman* lies in the interval [1, 444], addition of 259 will result in a larger *avoman*.

Example: The year 1242 was number seven ($1242 \bmod 19 = 7$) in the intercalary cycle with the *avoman* equal to 515. The previous intercalary year, 1240, was the fifth in the intercalary cycle and the distance between these years is two years. Thus, the earlier year has a 2WFM of $515 - 517 = -2$. Add 703 to this result and we find the 2WFM *avoman* is 701. The 2WFM *avoman* of the year 1242 is smaller than the previous 2WFM *avoman*, thus there is no day intercalated in the year 1242. The next year with an intercalary month is 1245, number ten in the intercalary cycle. As there are now three years between the previous intercalary year the *avoman* of year 1245 is $515 + 259 = 774$. As it is larger that 703 we subtract 703 and get 71. This is smaller than 515, thus the year 1245 has also no intercalary day. The next year in the intercalary sequence is 1248, number thirteen in the intercalary sequence. Again, the distance in years is three years and the new *avoman* will be $71 + 259 = 330$. As it is larger than the previous *avoman* the year 1248 will have an intercalary day.

We can now calculate the mean number of intercalary days in a 19-year cycle. There are always two two-year intervals in a Metonic intercalation cycle and five three-year intervals. For a two-year interval the probability of an intercalary day is 186/703. The corresponding probability for a three-year interval is 444/703. The

Table 2: Burmese intercalary years with intercalary days.

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | | | | | | x | x | x | x | x | x | x | x | x | x | x | | | | | | | x | x | x | x | x | x | x | x | x | x | | | |
| 5 | x | x | x | x | x | | | | | | | x | x | x | x | x | x | x | x | x | x | x | | | | | | | x | x | x | x | x | x | x |
| 7 | | | | | | | | x | x | x | x | | | | | | | | | | | | | x | x | x | x | x | | | | | | | |
| 10 | x | x | x | x | x | x | x | | | | | | | x | x | x | x | x | x | x | x | x | x | | | | | | | x | x | x | x | x | x |
| 13 | | | | x | x | x | x | x | x | x | x | x | x | | | | | | | x | x | x | x | x | x | x | x | x | x | | | | | | |
| 15 | x | x | x | | | | | | | | | | | | | x | x | x | x | | | | | | | | | | | | | x | x | x | x |
| 18 | | | | | x | x | x | x | x | x | x | x | x | x | x | | | | | | | x | x | x | x | x | x | x | x | x | x | | | | |
| 2 | x | x | x | x | | | | | | | x | x | x | x | x | x | x | x | x | x | x | | | | | | | x | x | x | x | x | x | x | x |
| 5 | x | x | x | x | x | x | x | x | x | x | | | | | | | x | x | x | x | x | x | x | x | x | x | x | | | | | | | x | x |
| 7 | | | | | | | | | | | | | x | x | x | x | | | | | | | | | | | | | x | x | x | x | x | | |
| 10 | | | x | x | x | x | x | x | x | x | x | x | | | | | | | x | x | x | x | x | x | x | x | x | x | | | | | | | x |
| 13 | x | x | | | | | | | x | x | x | x | x | x | x | x | x | x | | | | | | | x | x | x | x | x | x | x | x | x | x | |
| 15 | | | | x | x | x | x | x | | | | | | | | | | | | | x | x | x | x | | | | | | | | | | | |
| 18 | x | x | x | | | | | | | x | x | x | x | x | x | x | x | x | x | x | | | | | | | x | x | x | x | x | x | x | x | x |
| 2 | x | x | x | x | x | x | x | x | x | | | | | | | x | x | x | x | x | x | x | x | x | x | x | | | | | | | x | x | x |
| 5 | | | | | | x | x | x | x | x | x | x | x | x | x | | | | | | | x | x | x | x | x | x | x | x | x | x | | | | |
| 7 | | x | x | x | x | | | | | | | | | | | | | x | x | x | x | | | | | | | | | | | | | x | x |
| 10 | x | | | | | | | x | x | x | x | x | x | x | x | x | x | | | | | | | x | x | x | x | x | x | x | x | x | x | | |
| 13 | x | x | x | x | x | x | x | | | | | | | x | x | x | x | x | x | x | x | x | x | | | | | | | x | x | x | x | x | x |
| 15 | | | | | | | | | | x | x | x | x | | | | | | | | | | | | | x | x | x | x | | | | | | |
| 18 | x | x | x | x | x | x | x | x | x | | | | | | | x | x | x | x | x | x | x | x | x | x | | | | | | | x | x | x | x |

total mean number of intercalary days in the cycle is then 2 × 186/703 + 5 × 444/703 = 2592/703 solar days = 3.687055 days, exactly equal to the number of required days for synchronising the lunar calendar with the Moon and also the lunar calendar with the tropical year. To this extent there is no need for a solar calendar.

It is often seen stated that the intercalation of days follows a 57-year cycle requiring 11 intercalary days. It is true that very frequently there are 11 intercalary days in 57 years, but the canonical scheme presented above does not result in any recognisable pattern in which years the intercalary days should be inserted and cannot be used as an intercalary rule. Table 2 shows 35 intercalary cycles, each consisting of three 19-year intercalary cycles (3 × 19 = 57) for a total of 1996 years. The far-left column shows the year numbers in the intercalary cycle. Years with an intercalary month that also have an intercalary day are marked with a cross. Every cycle except cycles number 15 and 31 has indeed 11 intercalary days, the exceptions having 12 intercalary days, but there is no simple repeating pattern. Mathematically the intercalation pattern repeats only after 703 cycles. This range is unlikely to have been recognised.

A question is how the Burmese chose the pattern of intercalation years in the Metonic cycle. A possible answer could look like this:

The number of intercalary months is given by $m_1 = (7 \times m)/228$ where we use integer division and $m$ is the number of elapsed normal months. Each time this expression increases by one unit, there will be a new intercalary month. Now, suppose that we place ourselves at the end of *Waso*, month four. We can now calculate for what years in a 19-year sequence there has been a new intercalary month at this moment. Using $m$ = *cycle year*· × 12 + 4 in the expression for $m$, we find the years that the above expression increases by one for cycle years 3, 6, 8, 11, 14, 16, 19, which means that the previous years, 2, 5, 7, 10, 13, 15, 18 must have had an intercalary month. This is exactly the intercalation pattern used in the Makaranta calendar. The Arakanese calendar inserts the intercalary month after Tagu, the first month. Using $m$ = cycle year × 12 +1, we generate the intercalation pattern 2, 5, 8, 10, 13, 16, 18, which is actually a variant found in the historical record (Chatterjee, 1966; Eade, 1995).

## 1.3 The Solar Year

The original sidereal solar calendar has 292207 days in 800 solar years with a sidereal solar year of 365.25875 days. The backbone of the solar calendar is the *ahargana*, in Burmese *haragon* or *tawana*, the number of elapsed days since the epoch plus the New Year's Day. The Sanskrit term *ahargana* will be used in what follows. The formula for the *ahargana* at the end of the day of the beginning of a Burmese year is the integer result of (year × 292207 + 373)/800.

The number 373 is an epoch constant giving the mean age of the Sun in parts of 1/800$^{th}$ of a day at the beginning of the epoch. The final addition of one day brings the *ahargana* up to midnight on New Year's Day, the number of current days from the epoch.

The remainder of the division (year × 292207 + 373)/800 measures the age of the mean Sun on the beginning of the New Year's Day in units of 1/800$^{th}$ of a day. The 800-complement of this number is the part of the solar day that remains and is called the *kyammat*. The *kyammat* decreases by 207 units from New Year to New Year and when it is 207 or less in value it

Table 3: The changing month intercalation scheme in Thandeikta.

| | **1** | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Burmese Year | | x | | | x | | x | | | x | | | x | | x | | | x | |
| 1201 | | x | | x | | | x | | | x | | | x | | x | | | x | |
| 1217 | x | | | x | | | x | | | x | | | x | | x | | | x | |
| 1228 | x | | | x | | | x | | | x | | x | | | x | | | x | |
| 1263 | x | | | x | | | x | | x | | | x | | | x | | | x | |
| 1317 | x | | | x | | x | | | x | | | x | | | x | | | x | |
| 1328 | x | | | x | | x | | | x | | | x | | | x | | x | | |
| 1344 | x | | | x | | x | | | x | | | x | | x | | | x | | |

generates a solar leap year with 366 days. Note that 207/800 = 0.25875 is the excess over 365 days of the adopted sidereal solar year. The *ahargana* is further used for calculation of the longitudes of the planets.

The problem is that the lunar Metonic calendar is not happily married with this sidereal solar calendar. The sidereal solar year is 365.25875 – 365.24667 = 0.01208 days longer than the mean lunar tropical year. By the year 1100 in the Burmese Era the two calendars had drifted about 12 days apart and religious celebrations threatened to fall in the wrong season, very much the situation with the Western Julian calendar where Easter moved away from the true vernal equinox because the Julian calendar year is a little too long relative to the true tropical solar year.

The situation in Burma was worsened by a reform of the calendar, the Thandeikta (သံဒိဋ္ဌ) calendar, that uses the modern *Sūryasiddhānta* parameters for the Sun, 1577917828 days in 432000 years that was introduced in practice around the year 1200 in the Burmese Era (CE 1838). This sidereal year is even longer than the previous sidereal year and the drift accelerated. The remedy was to start changing the intercalation pattern for the lunar months making them occur earlier. This was done in several steps up to the present day. See Table 3, where the crosses mark the years in the 19-year cycle that are intercalary. The left column shows the Burmese years when the change was done. The corresponding Western year is the Burmese year increased by 638.

Secondly, the rule for inserting intercalary days was changed several times and these changes completely destroyed the original beauty and consistency of the original system. Today, there are no canonical rules for setting up future Burmese calendar dates, the intercalation being determined from time to time by a committee of calendarists. A suggestion of a new computer algorithm for a reformed Myanmar calendar can be found on the Internet (Yan Naing Aye, 2013).

The Arakanese and Makaranta calendars are unique among the Indian-influenced calendars in Southeast Asia in using a Metonic intercalation pattern. There is only one Indian canon that uses this scheme, the *Romakasiddhānta* (Neugebauer and Pingree, 1970–1971; Sastry, 1993; van der Waerden, 1988). As the name indicates, this canon has Hellenistic origins. Its epoch is CE 21 March 505 or Śaka 427. The scheme for the computation of the excess *tithis* in these original Burmese calendars is exactly paralleled in the *Romakasiddhānta*. It is tempting to assume that the *Romakasiddhānta* was a precursor to the Burmese calendar. However, the presently known facts about the *Romakasiddhānta* are too scanty to draw any safe conclusions.

In the later Thandeikta scheme the New Year *ahargana*, $h_0$, is computed by

$$h_0 = [\text{year} - 1100 + (\text{year} - 1100)/193 + 17742]/800 + 1, \quad (1)$$

the New Year *kyammat* by

$$k_0 = 800 - [\text{year} - 1100 + (\text{year} - 1100)/193 + 17742]/\text{mod } 800 \quad (2)$$

and the *avoman* by

$$[11 \times h_0 + (\text{year} - 1100)/25 + 176] \text{mod } 692. \quad (3)$$

In Burma there is sometimes used a 12-year cycle for years where the years are specified by the Sanskrit names for the lunar months.

## 2 THAILAND, LAOS AND CAMBODIA

### 2.1 The Sources

The first description of the calendar in the regions of Southeast Asia mainland outside Burma and Vietnam came to Europe with the return of Simone de la Loubère from a visit to Siam in CE 1687. La Loubère (1642–1729) was a French diplomat and mathematician who led an embassy to Siam (modern Thailand) on a mission instigated by the King Louis XIV of France. On his return, at the request of the King he wrote a description of his travels, which were published in two volumes under the title *Du Royaume de Siam* (Loubère, 1689). An English translation was published in London in 1693 as *A New Historical Relation of the Kingdom of Siam*. In the second volume Loubère gives a detailed description of Siamese astronomical calculations (see Section 6.1), with explanations added by the French chief astronomer Giovanni Cassini (1625–1712). Cassini was both exasperated and impressed by the Siamese methods of calculation:

> This method is extraordinary. Tables are not used; but only addition, subtraction, multipli-

> cation, & division of certain numbers, for which one at first cannot see the basis, nor how they are related. (Loubère, 1689: 142; our English translation).

Loubère (1689: 202–203) also gives equivalences between four Siamese and Western dates:

- 24 June 1687 = 1 waning, month 8 (Ashada) 2231 (Buddhasakarat era, inclusive reckoning)
- 20 October 1687 = 15 waxing, month 11 (Asvina)
- 11 December 1687 = 8 waxing, month 1 (Margasirsha)
- 22 December 1687 = 3 waning, month 1 (Margasirsha)

The dates are lunar dates giving the age of the Moon. The first two reveal interesting information: the distance between them is 118 days, precisely equal to four lunar months, but the difference in months is only three (11–8). The conclusion (also made by Cassini, who demonstrated acuity in his analysis) is that there must have been an intercalary month in between. In fact, according to the canonical Thai calendrical rules this year should indeed be intercalary.

The second source of the calendrical schemes of this region came much later with the publication of *Astronomie Cambodgienne* (Faraut, 1910) by the French engineer Felix Gaspar Faraut (1846–1911). Faraut visited Cambodia in 1880–1881 and became Councillor and Chief Engineer of King Norodom I (1834–1904). During his stay he also attended a course on Khmer astronomy by the Royal Astrologer, Daung Okgna Hora Thpdey Chang Vang, on the methods that the latter employed to determine the positions of the planets and to construct the luni-solar calendar. Faraut had a difficult task, being exposed to Khmer technical terminology that had no self-explanatory meaning and to a set of mechanical mathematical operations that had no obvious theoretical basis, just a set of procedures. Also, when he returned to France in 1884 and planned to publish his results, he found that all of his study notes from the course had disappeared. Luckily, two years later he found them, and eventually they were published. Despite its many errors and misunderstandings, Faraut‘s book is our main source on the workings of the old calendar and astronomy of Thailand, Cambodia and Laos. These workings have been the basis of the computer application SEAC (Southeast Asian Calendars) developed by Eade and Gislén that also handles the Burmese calendars.

The third source of information is the monumental astronomical/astrological manual in Thai by Luang Wisandarunkorn (1997). Most of the book deals with astrology, but there are model calculations of planetary longitudes and eclipses that in many cases complement, vindicate and illuminate Faraut‘s descriptions.

The calendar in Laos has been dealt with in detail by Prince Phetsarath of Laos (see Phetsarath 1956; 1973), and there is an extensive numerical treatment by Dupertuis (1981).

## 2.2 The Calendar

The epoch of the Thai Chulasakarat era (small era) is the same as for the Burmese calendars, namely CE 22 March 638. But there are other eras in use in the region: the Mahasakarat era (large era), identical with the Śaka Era and with epoch CE 17 March 78; the Buddhasakarat era with epoch 11 March 544 BCE, the day Buddha attained *parinwāna* or Nirvana; and the Anchansakarat era, with epoch 10 March 691 BCE. This last era, which is not often encountered, appears to have been a device to deal with events before the Buddha era, thus avoiding negative reckoning. These eras will not be much studied here; their calendrical schemes are identical with that of the Chulasakarat era except for having different epoch constants. The basic machinery for the calendrical and astronomical calculations derive from the Indian *Sūryasiddhānta* albeit in a slightly simplified version.

The Thai lunar months (Table 4), like the Burmese ones, have alternating 29 and 30 days and there is a lunar intercalary month, *adhikamat*. Unlike Indian reckoning in which extra lunar months were observed as they fell due, the *adhikamat* was confined to a second *Ashada* (*Wazo* in Burma), which had 30 days. There is also occasionally an intercalary day, *adhikawan*, inserted at the end of the previous month *Jyestha*. A distinction between the Thai and Burmese systems, one with more dislocating effect than one might have imagined, is that the Burmese mode says that a year with an extra day can occur only in a year that also has an extra month, whereas the Thai system says that a year with an extra month cannot also have an extra day.

The Thai names of the lunar months are almost identical with the Pali names. In what follows, we will refer to the months by their Sanskrit names but without the diacritics.

In most Thai calendrical records, the month is referred to by a number instead of by its name of which there are three styles. Table 5 shows the equivalences used. Intercalary months are referred to by doubling the month number of intercalated month. So, for instance, an intercalated Ashada in the Central/Sukhothai system is written 88. The Cambodian names are the less common alternatives for the Sanskrit ones (Eade, 1995).

The calculation of the solar and lunar parameters in La Loubère is somewhat different from that in Faraut (1910) and Wisandarunkorn (1997)

Table 4: Lunar month names.

| Thai | Days | Lao | Khmer | Pali | Sanskrit |
|---|---|---|---|---|---|
| Chittra (จิตร ) | 29 | Chit | Chaet | Citta | Caitra |
| Wisakha (วิสาข) | 30 | Wisakha | Vesak | Visakha | Vaiśākha |
| Chettha (เชษฐ) | 29/30 | Set | Jais | Jeṭṭha | Jyeṣṭa |
| Asalha (อาสาฬห) | 30 | Asalaha | Ashad | Āsāḷha | Āṣādha |
| Sawana (สาวน) | 29 | Sawana | Srap | Sāvana | Śravaṇa |
| Phatrabot (ภัทรบท) | 30 | Phatthrabot | Phutrobot | Poṭṭhapāda | Bhādrapada |
| Atsawayut (อัศวยุช) | 29 | Atsawayut | Asuj | Assuayuja | Aśvina |
| Kattika (กัตติกา) | 30 | Karttika | Kadhek | Kattikā | Kārttika |
| Mikasira (มิคสิร) | 29 | Mikhasina | Mekasay | Māgasira | Mrgaśīrṣa |
| Putsa (ปุสส) | 30 | Putsa | Bos | Phussa | Pauṣa |
| Makha (มาฆ) | 29 | Mat | Meak | Māgha | Māgha |
| Phakkhun (ผัคคุณ) | 30 | Phakkhun | Phagaun | Phagguṇa | Phālguna |

and is based on the lunar calendar. It seems to be related to an earlier calendrical epoch in Siam and is in many ways similar to the corresponding Burmese calculation. The era used in La Loubère's calculation is the Chulasakarat era with elapsed years. Given the year *y*, the elapsed lunar months *m* of the year, and the elapsed lunar days of the month or *tithis, t,* the procedure is as follows:

1) Compute the number of elapsed normal lunar months from $m_0 = 12 \times y + m$.
2) Compute the number of intercalary months $m_1 = (m_0 \times 7)/228$. This assumes a Metonic calculation that is not, as will be seen, the case for Siam. The information in La Loubère shows that the Siamese year 1049, corresponding to CE 1687, was a year with an intercalary month which it was not in the Burmese calendar with Metonic intercalation.
3) Compute the total number of elapsed *tithis* $T = 30 \times (m_0 + m_1) + t$.
4) Compute the *avoman*: $a = (t \times 11 + 650) \bmod 703$.
5) Compute the *ahargana*: $h = T - (T \times 11 + 650)/703$. The *ahargana* (lit. 'collection of days') is the number of elapsed solar days since the epoch. The relation uses the fact that a *tithi* corresponds to 692/703 of a solar day.

Once the *avoman* and *ahargana* are calculated they are used in the same way as in Faraut (for Cambodia) and Wisandarunkorn (for Thailand) to calculate the longitudes of the Sun and the Moon and the planets.

Table 5: Month equivalences.

| Sanskrit | Cambodia | Central/ Sukhothai | Keng Tung | Chiang Mai |
|---|---|---|---|---|
| Caitra | Magha | 5 | 6 | 7 |
| Vaisakha | Madhava | 6 | 7 | 8 |
| Jyestha | Sukra | 7 | 8 | 9 |
| Ashadha | Suci | 8 | 9 | 10 |
| Sravana | Nabhas | 9 | 10 | 11 |
| Bhadrapada | Nabas | 10 | 11 | 12 |
| Asvina | Isha | 11 | 12 | 1 |
| Karttika | Urja | 12 | 1 | 2 |
| Margasirsha | Sahas | 1 | 2 | 3 |
| Pausha | Sahasya | 2 | 3 | 4 |

The calculations for the solar calendar in Faraut (1910) and Wisandarunkorn (1997) are identical to the early Burmese calendars, as is evident by their arriving at identical results (Eade, 1995). There is the same rule for a solar leap year—that if the *kyammat* (or in Thai the *kammacabala,* see below) is less than or equal to 207, the solar year is a leap year with 366 days. However, the rules for intercalating the lunar months are different, more complex, and not Metonic. We will use the *suryayatra* rules that seem to be more reliable (Eade, 2000). The solar new year occurs on the day when the mean solar sidereal longitude is zero, i.e. when the mean Sun enters the first zodiacal sign. This is in Thai *thalœngsok*. The true Sun has zero longitude about two days earlier, the *songkran*, and the interval between the two is used for celebration. The solar new year occurs in the lunar month of *Caitra* or sometimes in the following month *Vaisakha*. The basic rule is that the solar year can never start earlier than 6 *Caitra* or later than 5 *Vaisakha*, the following lunar month, although this latter date may, by a subsidiary rule, be pushed to 6 *Vaisakha*. As the normal lunar year is 11 or 12 days shorter than the solar year (depending on whether the previous solar year is a leap year or not) the solar new year will start the corresponding number of days later in the lunar calendar if there is no intercalary month. This means that if the start of the lunar year occurs in the interval later than 24 *Caitra* and before or on 6 *Vaisakha* there is a need for an intercalary lunar month. If a lunar year starts on 24 *Caitra* and the next year would start on 6 *Vaisakha* there is also an intercalary year.

There is an exception to these rules—that if a lunar year starts on 25 *Caitra* and the next year would start on 5 *Vaisakha* there is no intercalation, as it would sometimes generate two years in sequence with intercalary months. These rules effectively lock the lunar calendar to the sidereal solar one and in this way avoid the problems that the Burmese calendar has.

It is possible to compute the average frequency of the intercalation of months using the

fact that the intercalation rules keep the solar and lunar calendars in step.

Nineteen sidereal solar years have 19 × 365.25875 = 6939.91625 days. This corresponds to 6939.91625/29.53058321 = 235.0077613 synodic months. Nineteen years each with twelve synodic months contain 19 × 12 = 228 months. Thus, we have on average 235.0077613 – 228 = 7.0077613 intercalary lunar months in a 19-year period in order to keep the solar and lunar calendars aligned. This is very close to the Metonic intercalation frequency, though the intercalation pattern will not be fixed but will recede slowly within a 19-year cycle in a way similar to the recession of intercalary cyclic years in the Burmese Thandeikta calendar.

The rule for the intercalation of a day in the lunar calendar uses the New Year *avoman*. This is computed using the New Year *ahargana*, $h_0$, computed as in the Makaranta calendar by

$h_0$ = (year × 292207 + 373)/800 + 1 (4)

where integer arithmetic is used. The New Year *avoman*, $a_0$, is then computed by

$a_0 = (h_0 \times 11 + 650) \bmod 692$ (5)

If the avoman is equal to zero it is changed to 692. The remainder of the division

(year × 292207 + 373)/800 (6)

is the excess time, expressed in 1/800th of a day or the ‗age' of the Sun at the end of the New Year day. The quantity 800 minus the remainder is the *kammacabala* corresponding to the Burmese *kyammat*. If the *kammacabala* is less than or equal to 207 the solar year is a leap year with 366 days.

Example: Compute the *ahargana* and the New Year *kammacabal*a of the Chulasakarat year 1238:

(1238 × 292207 + 373)/800 = 452190 and remainder 639. The *ahargana* is 452190 + 1 = 452191 and the *kammacabal*a = 800 – 639 = 161. As this is less than or equal to 207, the year is a solar leap year.

Example: Compute the New Year *avoman* for Chulasakarat 1238:

(452191 × 11 + 650)/mod 692 = 655. The *avoman* is 655.

The *avoman* increases by 11 units each day. During a normal solar year, the New Year *avoman* increases by (365 × 11) mod 692 = 555, during a solar leap year by 555 + 11 = 566. The distance of these numbers from 692 is 137 and 126 respectively. An increase of 555 is, in modular language, the same as a decrease of 137. If the New Year *avoman* of a normal year is equal to 137 or less, it means that the lunar calendar needs an intercalary day; for a leap year there will be an intercalary day if the New Year *avoman* is equal to 126 or less. However, this rule can mean that an intercalary day falls in a lunar year with an intercalary month. This has to be avoided and there are quite complicated rules on how to move the intercalary day to one of the adjacent years.[4] This is a step where it is quite probable that in practice other rules were used, for instance by always moving the day to the following or always to the preceding year. This expedient would in the long run have no lasting effect but would make the calendar sometimes deviate a day from the canonical calendar.

We can also calculate the frequency of day intercalation, irrespective of the precise insertion rules. The probability of having a leap year is 207/800, the probability of a normal year (800 – 207)/800 = 593/800. The probability of an intercalary day is 126/692 and 137/692 respectively. Thus, the joint probability is:

[(126/692 × 207)/800] + [137/(692 × 593)/800] = 0.1938638

or on average 19 × 0.1938638 = 3.6834122 days in 19 years. We have the relation

19 sidereal solar years = 19 × 365.25875 = 6939.91625 days

19 normal lunar years with 354 days plus on average 7.0077613 intercalary years with 30 days give

(19 × 354) + (7.0077613 × 30) = 6936.232839 days.

Add to this the 3.6834122 days from the day intercalation and we get 6939.91625—exactly matching the mean number of days in a 19-year year period. By this means the Thai intercalation scheme achieves a perfect synchronisation of the sidereal solar and lunar calendars and with the Moon.

There are a few other quantities that are used in calendrical calculations and are often specified in the records. The *uccabala* relates to the position of the Moon's apogee. It is calculated using the formula

*uccabala* = (*ahargana* + 2611) mod 3232 (7)

where 2611 is an epoch constant. The number 3232 is the period of rotation in days for the apogee.

The *masaken* counts the number of elapsed lunar months. First the number of *tithis* is computed: a solar day is equal to 703/692 of a *tithi* and the *tithi* was 650/692 at the epoch. As each lunar month is equal to 30 *tithis*, the number of lunar months is simply the tithis divided by 30.

*masaken* = [(*ahargana* × 703 + 650)/692]/30 (8)

The *tithis* within the lunar month is computed by

[(*ahargana* × 703 + 650)/692] mod 30 (9)

Example: Compute the *uccabala*, *masaken*,

and *tithi* for New Year 1238, *ahargana* 452191.

(452191+2611)mod 3232 = 2322, the *uccabala*.
(452191 × 703 + 650)/692 = 459379
459379/30 = 15312, the number of elapsed lunar months since the epoch.
459379mod 30 = 19, the *tithi*.

Since the system was implemented locally over a wide area for centuries, as is evidenced by monastic inscriptions, it may be concluded that the numbers that caused the system to function from year to year were easily memorised and reliably passed from generation to generation.

## 2.3 The Sexagesimal Calendar

Another calendar component used in Northern Thailand, Laos, and also in Burma is the cyclic sexagesimal calendar. In Northern Thailand it is used for both days and years, in Burma only with a duodecimal cycle for years. It is built from the combination of a decimal with a duodecimal cycle but such that only odd or even elements are paired. This will give precisely sixty different combinations. The Thai names of the decimal cycle items are: *kap*, *dap*, *raway*, *moeng*, *poek*, *kat*, *kot*, *ruang*, *tao* and *ka*.

Table 6: Names of the Watches.

| Time | Thai | Lao |
|---|---|---|
| 06:00–07:30 | *tut chao* | *tuttang* |
| 07:30–09:00 | *klong ngai* | *ngay* |
| 09:00–10:30 | *træ thiang* | *te kaeu thieng* |
| 10:30–12:00 | *thiang* | *thieng* |
| 12:00–13:30 | *tut chai* | *tutsay* |
| 13:30–15:00 | *klong kham* | *leng* |
| 15:00–16:30 | *træ kham* | *thè kaeu kham* |
| 16:30–18:00 | *[phat] kham* | *phat lam* |
| 18:00–19:30 | *tut dük* | *tuttang* |
| 19:30–21:00 | *klong dük* | *deuk* |
| 21:00–22:30 | *træ dük* | *thè kaeu thieng* |
| 22:30–00:00 | *dük* | *thieng khun* |
| 00:00–01:30 | *tut rung* | *tutsay* |
| 01:30–03:00 | *klong rung* | *khua* |
| 03:00–04:30 | *træ rung* | *thè kaeu hung* |
| 04:30–06:00 | *rung* | *phat lan* |

The duodecimal series is: *cai*, *pao*, *yi*, *mao*, *si*, *sai*, *sanga*, *met*, *san*, *rao*, *set* and *kai*.

Sometimes also the Thai animal names are given: *Chuat*, *Chalu*, *Khan*, *Tho*, *Marong*, *Maseng*, *Mamia*, *Mamae*, *Wok*, *Rakaa*, *Cho*, *Kun*.

These names are the same as in the Chinese duodecimal series: rat, ox, tiger, rabbit, dragon, snake, horse, goat, donkey, rooster, dog and pig.

The sexagesimal day cycle is often combined with the seven-day cycle of weekdays to generate a larger 420-day cycle.

## 2.4 Time Measure

Time of the day is sometimes measured in watches where the period from one dawn to the next is divided into eight day- and eight night-watches, giving 90 minutes for each (see Table 6). By South-east Asia reckoning the subunits of time are the *pada/bat* of six minutes, the *nadi*, or sixtieth of a day (24 hours), 24 minutes, and the *nalika* of 60 minutes.

## 2.5 King Rama IV's Lunar Calendar

A special Thai lunar calendar is the Pakkhakhanana (ปักขคณนา, fortnight calculation) calendar (Chunpongtong, 2008) invented by the Thai King Rama IV or Mongkut (CE 1804–1868; Saibejra, 2006). He noted that the phases of the Moon in the Thai lunisolar calendar were sometimes displaced by up to two days relative to the true Moon and was concerned that the Buddhist sabbath days would not be celebrated at the stipulated times. The Pakkhakhanana calendar, although using the mean Moon, gives phases of the Moon that are much closer to the real Moon than the standard Thai calendar.

The calendar uses a board with five sets of rows of Khmer letters, ម (M, for *Maha* or big) and ច (C, for *Chula*, small) and with pegs to mark the settings (see Figure 1a). Figure 1b shows the schematic layout for 11 February 2019, Magha 7 waxing 1380, Julian Day 2458526. The setting in the second figure is not the same as in the first one. The scheme is based on fortnights. i.e. the waxing and waning parts of a lunar month that each one can have either 14 or 15 days (whereas the standard calendar always has 15 days, expressed as 14 waxing days and full Moon day).

The letter in a specific set of rows determines which row, M or C, to use in the next set of two rows below it. The bottom rows determine whether the fortnight has 15 (M) or 14 (C) days. These rows are not shown on the Pakkhakhanana board. For each day, the number in the bottom row is stepped up one step. As the number reaches 14 or 15, the counting starts again from 1 and the position in the set of rows above is stepped up by one to the right. As the steps reach the end of the row, the position in the set of two rows above is stepped one step to the right and so on. All the time the choice of the row where to begin within the two set of rows is determined by the letter in the set above. Full Moons and New Moons occur when the number in the lowest rows is fourteen or fifteen, quarter Moons when it is eight. The scheme is based on a mean lunar half-month of 14.765297 days. The first day of the calendar is Saturday 28 January 1736, Julian Day 2355148 when the Moon was 1 waning.

The procedure to compute the setting pattern of the board is as follows:

1) Subtract 2355147 from the Julian Day.
2) Divide the result by 16168, increase the quotient by 1, keep the remainder.
3) Divide the remainder by 1447, increase the quotient by 1, keep the new remainder.
4) Divide the remainder by 251, increase the quotient by 1, keep the new remainder.
5) Divide the remainder by 59, increase the quotient by 1, keep the new remainder.
6) Divide the remainder by 15, increase the quotient by 1, keep the new remainder
7) The remainder is the day number in the half-month.

The reason for the numbers 15, 59, 251, 1447, and 16168 is that they are chosen to be successively more close approximations of days of an integer number of half-months. They correspond respectively to 1, 4, 17, 98, and 1095 half-months.

Example: 11 February 2019, Julian Day 2458526.

1) 2458526 – 2355147 = 103379
2) 103379/16168 = 6:6371, 6 + 1 = 7
3) 6371/1447 = 4:583, 4 + 1 = 5
4) 583/251 = 2:81, 2 + 1 = 3
5) 81/59 = 1:22, 1 + 1 = 2
6) 22/15 = 1:7, 1 + 1 = 2

The board setting pattern is 7:5:3:2:2:7 as shown in Figure 1b. The rule will sometimes give a setting that needs to be adjusted.[5] The number of elapsed half-months is computed from this setting by (7–1) × 1095 + (5–1) × 98 + (3–1) × 17 + (2–1) × 4 + 2 = 7002. As the number of elapsed half-months is even, the Moon will be waxing 7.

The scheme generates a lunar calendar with a more even distributions of half-months of 14 days than the standard Thai luni-solar calendar and is closer to the real Moon phases. The calendar pattern repeats after 289577 days. A test run with a computer implementation of the calendar from CE 1850 to 2000 shows that the maximum deviation from the mean astronomical Moon only is ±0.5 days. At present the calendar is only used by Dhammayuttika Nikaya, an order of the Theravada Buddhism in Thailand.

## 3 CONCLUDING REMARKS

The original Burmese calendars are unique in Southeast Asia in using a Metonic intercalation. Also, the lack of connection between the lunar and solar calendars is specific. It would be highly interesting to investigate the origins of these calendars once more information becomes available. One possibility is a connection with the Indian *Romakasiddhānta* with which they share many similarities (Gislén, 2019). The later Thandeikta calendar tries to remedy the discrepancy between the lunar and solar calendars by modifying the intercalation scheme.

The Thai calendar achieves a perfect synchronization between the lunar and solar calendars. However, the use of a sidereal solar calendar means that it will drift slowly in relation to the real seasons. The solar New Year, originally chosen to start at the vernal equinox at the epoch in CE 638, now starts about a month later.

Figure 1a: A Pakkhakhanana board.

11 February 2019 CE (7 Magha1380 CS)

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | M | C |
| M | C | C | C | C | C | C | C | C | C | C | M | | | | | | | |
| C | C | C | C | C | C | C | C | C | C | M | | | | | | | | |
| M | M | M | M | M | M | M | C | | | | | | | | | | | |
| C | M | M | M | M | M | C | | | | | | | | | | | | |
| M | C | C | C | M | | | | | | | | | | | | | | |
| C | C | C | M | | | | | | | | | | | | | | | |
| M | M | M | M | M | C | | | | | | | | | | | | | |
| C | M | M | M | C | | | | | | | | | | | | | | |
| M | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | | | |
| C | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | | | | |

Figure 1b: The Pakkhakhanana board, schematic layout.

It is very important to realise that there are canonical calendar schemes that are based on sound astronomical facts and constructed by highly educated and skilled experts in the field.

The canonical rules for computing the calendar were codified in a set of inherited rules, much like a computer program, which if followed, generated the desired result. This procedure did not require that the person doing the calculation had any understanding of the underlying astronomical model. This way of working has some obvious advantages: the many horoscope calculations recorded in the temples could be done by unskilled monks. The drawback is that once a rule was misunderstood or distorted, the error could propagate without possible correction for all future time.

Such distortions, however, are quite rare considering that this system has worked for the order of a millennium. Another more frequent issue could be that there were sometimes in the practical application of the rules shortcuts or simplifications made, of which there is some evidence, or intercalation changes made at the whim of some ruler. When a satisfactory procedure has been established that accurately and consistently replicates the data to be found in the Thai inscriptions, it is something of an aggravation that there is nonetheless some tendency for the data to represent a one-day difference from one‘s expectation. One takes into account here that there are three kinds of lunar year: a normal one of 354 days, and two others in which either an extra day (355 days) or an extra month (384 days) is added as a means of causing the lunar years to keep pace with the solar years. In the case where an extra day is required there were some complicated theoretical rules set up to determine which years should receive the extra day—a matter on which even today there is a discussion. One consequently suspects that the one-day differences to be met with are the result not of minor computation errors, but of a settled difference in procedure.

The very complicated calculations of the true longitudes of the planets for the horoscopes were sometimes done at some fixed time intervals and not always on the day as they should have been. Corrections for calculating true longitude from mean longitude were sometimes added instead of subtracted or vice versa. Also, in some cases there have been errors in the procedure of transferring the computed calendrical data to the actual written record. The digits for one (၁), eight (၈), and zero (၀) are very similar in Burmese as are four (๔) and five (๕) in Thai. Any small defect could easily change one digit to the other. This means that when comparing the actual calendrical field records, the fact that some numerical information deviates from what is expected from a canonical calculation does not necessarily mean that the record or the calendar is wrong. It is better to characterise it as different. Luckily many of the records contain redundant calendrical data making it possible to spot such deviations.

Another source of apparent error is that the astronomic day starts at midnight but the civil day at sunrise or for villagers, ‗when they could see lines in the palm of their hand‘ (Diller, 2000). This means that depending on the convention an event could be assigned to one of two different days and weekdays if the time of the event occurred in the interval between midnight and sunrise.

## 4 NOTES

1. This is the second paper in a series that reviews the traditional calendars of Southeast Asia. The first paper (Gislén and Eade, 2019) provided an introduction to the series.
2. For specialist astronomical terms used in this paper see the Glossary in Section 6.3.
3. The Burmese and Thai astronomical and calendrical calculations are based on integer arithmetic. Thus, the division of two numbers, for instance 10/3 gives the result 3 with a remainder of 1. In this paper we use the mathematical modulus function where 10 mod 3 means the remainder of 10 divided by 3. Actually, we use a slightly different definition: if the remainder is 0 it is replaced by the divisor, 20 mod 5 is then 5, not 0.
4. For Thai rules for intercalary days see Section 6.2 below.
5. For example, starting with 98956, the rule gives the setting 7:2:2:5:1:14. However, there are only four columns for the fourth item and the number 5 must be adjusted to 4. This will add 59 to the remainder and give the correct setting 7:2:2:4:5:13.

## 5 REFERENCES


Chatterjee, G.K., 1996. Traditional calendar of Myanmar (Burma). *Indian Journal of History of Science*, 33, 143–160.

Chunpongtong, L., 2008. *Thai Calendar: Astronomy and Mathematics*. Bangkok, National Astronomical Research Institute of Thailand (in Thai).

Diller, A., 2000. *Thai Time*. See https://openresearch-repository.anu.edu.au/bitstream/1885/41890/3/thai_time.html

Dupertius, S., 1981. Le calcul du calendrier *laotien*. *Péninsule*, 2(3), 17–79 (in French).

Eade, J.C., 1995. *The Calendrical Systems of Mainland South-East Asia*. Brill, Leiden.

Eade, J.C., 2000. Rules for interpolation in the Thai calendar: *suryayatra* versus the *sasana*. *Journal of the Siam Society*, 88, 195–203.

Faraut, F.G., 1910. *Astronomie Cambodgienne*. Saigon, F.H. Schneider (in French).

Gislén, L., 2018. On lunisolar calendars and intercalation schemes in Southeast Asia. *Journal of Astronomical History and Heritage*, 21, 2–6.

Gislén, L., 2019. A hypothetical *Romakasiddhānta*

*Calendar*. *Journal of Astronomical History and Heritage*, 22, 339–341.
Gislén, L., and Eade, C.J., 2019. The calendars of Southeast Asia. 1: Introduction. *Journal of Astronomical History and Heritage*, 22, 407–416.
Htoon-Chan, 1918. *The Arakanese Calendar. Third Edition*. Rangoon, Rangoon Times Press.
Irwin, A.M.B., 1909. *The Burmese and Arakanese Calendars*. Rangoon, Hanthawaddy Printing Works.
Loubère, S. le, 1691. *Du Royaume de Siam*, *Tome 2*. Paris, Jean Baptiste Coignard (in French).
Neugebauer, O., and Pingree, D., 1970–1971. *The Pañcasiddhantika by Varahamihira*. København, Historisk-filosofiske Skrifter udgivet af det Kongelige Danske Videnskabernes Selskab, 6(1).
Ôhashi, Y., 2006. The riddle of the cycle of intercalation and the sidereal year: an aspect of the mainland South-East Asian calendars. In Chen, K.Y., Orchiston, W., Soonthornthum, B., and Strom, R. (eds.). *Proceedings of the Fifth International Conference on Oriental Astronomy*. Chiang Mai, Chiang Mai University. Pp.149–154
Phetsarath, S.A., 1956. Le calendrier Lao. *France-Asie*, 118–120, 787–812 (in French).
Phetsarath, S.A., 1973. *Astrologie Laotienne* (first part by Maha Vivalong). Vientiane, Lycée Fangoum (in French).
Saibejra, N., 2006. King Mongkut: the Father of Thai Science. In Chen, K.-Y., Orchiston, W., Soonthornthum, B., and Strom, R. (eds.). *Proceedings of the Fifth International Conference on Oriental Astronomy*. Chiang Mai, Chiang Mai University. Pp. 15–18.
Sastry, T.K., 1993. *Pañcasiddhāntika by Varahamihira.* Madras, Adyar (P.S.S.T. Science Series No. 1).
van der Waerden, B.L., 1988. On the Romakasiddhânta. *Archive for History of Exact Sciences*, 38, 1–11.
Wisandarunkorn, L., 1997. *Khamphi Horasasat Thai (Standard Thai Astrological Scripture)*. Bangkok, Inter-print (in Thai).
Yan Naing Aye, 2013. *Algorithm, Program and Calculation of Myanmar Calendar.* See http://coolemerald.blogspot.com/2013/06/algorithm-program-and-calculation-of.html (in Burmese with English translation).

## 6 APPENDICES

### 6.1 Extract from La Loubère's *Du Royaume de Siam*

Régles pour trouver le lieu du Soleil & de la Lune au temps de la naissance de quelqu'un.

I.

1. Posez l'Ere.
2. Soustrayez l'âge de la personne de l'Ere, vous aurez l'âge de la naissance.
3. Multipliez'la par 12.
4. Ajoûtez-y le nombre des mois de l'année courante: & pour cela, si l'année courante est *Attikamaat*, c'est-à-dire, si elle a 13 mois de la Lune, vous commencerez à compter par le 5 mois; que si elle n'est point *Attikamaat*, vous commencerez à compter par le 6 mois.
5. Multipliez par 7 le nombre trouvé art. 4.
6. Divisez la somme par 228.
7. Joignez le quotient da la division au nombre trouvé art. 4; cela vous donnera le *Maasaken* (cést'à-dire, le nombre des mois) que vous garderez.

II.

1. Posez la *Maasaken*.
2. Multipliez par 30.
3. Joignez-y les jours du mois courant.
4. Multipliez par 11.
5. Ajoûtez-y encore le nombre de 650.
6. Divisez par 703.
7. Gardez le numerateur que vous apellerez *Anamaan*.
8. Prenez le quotient de la fraction trouvé art 6, & le soustrayez du nombre art. 3: le reste sera l'*horoconne* (c'est-à-dire, le nombre des jours de l'Ere) que vous garderez.

III.

1. Posez l'*horoconne*.
2. Divisez par 7.
3. Le numérateur de la fraction est le jour de la semaine. *Nota*, Que le premier jour de la semaine est le Dimanche.

IV.

1. Posez l'*horoconne*.
2. Multiplez-le par 800.
3. Soustrayez-en 373.
4. Divisez-le par 292207.
5 Le quotient sera l'Ere, & le numérateur de la fraction sera le *Krommethiapponne*, que vous garderez.

V.

1. Posez le *Krommethiapponne*.
2. Soustrayez-en l'Ere.
3. Divisez le reste par 2.
4. Negligeant la fraction, soustrayez 2 du quotient.
5. Divisez le reste par 7: la fraction vous donnera le jour de la semaine.

*Nota*, Que quand je diray la fraction, je n'entends parler que du Numérateur.

VI.

1. *Horoconne*.
2. Soustrayez-en 621 [or add 3232 – 621 = 2611]
3. Divisez le reste par 3232.
4. La fraction s'appelle *Outhiapponne*, que vous garderez.

Si vous voulez avoir le jour de la semain par, l' *Outhiapponne*, prenez le quotient de la division susfaite; multiplies-le par 5; puis joignez.le a l' *Outhiapponne*; puis soustrayez-en 2 jours; divisiez par 7, la fraction marquera le jour.

Tout ce que dessus s'appelle *Poulasouriat*, comme qui diroit la force du Soleil.

VII.

1. Posez le *Krommethiapponne*.
2. Divisez-le par 24350.
3. Gardez le quoirient, qui sera le *Raasi*, c'est à-dire, le Signe où sera le Soleil.
4. Posez la fraction de la division susdite, & la divisez par 811.
5. Le quotient de la division sera le *Ongsaa*, c'est à-dire, le degré où sera le Soleil.
6. Posez la fraction de cette division, & la divisez par 14.
7. Le quotient sera le *Libedaa*, c'est-à-dire, la minute.
8. Soustrayer 3 du *Libedaa*.
9. Mettez ce qui est au *Libedaa* au dessus de *l'Ongsaa*, & *l'Ongsaa* au dessus du *Raasi*: cela fre une figure qui s'appellera le *Matteniomme* du Solelei que vous garderez: Je croy que c'est *locus medius Solis*.

Sections VIII and IX treat the calculations of the true longitude of the Sun.

X. Pour la Lune pour trouver le matteiomme la Lune.

1. Posez l'*anamaan*.
2. Divisez-le par 25.
3. Mépriez la fraction, & joignez le quotient avac l'*anamaan*.
4. Divisez le tout par 60 le quotient sera *ongsaa* la fraction sera *libedaa*, & vous mettrez un 0 au rasi.
5. Posez autant de jours que vous en avez mis cy-dessus au mois courant sect. 2. II.3.
6. Multiplez ce nombre par 12.
7. Divisez le tout par 30, le quotient, mettez-le au *rasi* de la figure précedente qui a un 0 au rasi, & la fraction joignez-le à l'*ongsaa* de la figure.
8. Joignez toute cette figure au *mateiomme* du Soleil.
9. Soustrayez 40 du *libedaa*. Que si cela ne ce peut, vous tirez 1 du *ongsa* qui vaudra 60 *ibedaa*.
10. Ce qui restera dans la figure est le *matteiomme* de la Lune cherché.

## 6.2 Thai Rules for Intercalary Days

The rules for the insertion of intercalary days ensure that the flow of weekdays is uninterrupted. The rules as given in Faraut (1910) are very difficult to understand and to apply in practice. Below is a simpler equivalent scheme in which three basic pieces of information are needed:

1) The type of year: normal, year with intercalary day, year with intercalary month and year with both intercalary day and month, below denoted A, B, C, and BC respectively. Years BC have a collision between intercalary day and month must be adjusted in the Thai scheme, moving the intercalary day to one of the adjacent normal years. The type of year can be calculated by using the rules outlined in this paper.
2) The solar New Year weekday. This is easily computed from the solar New Year *ahargana* ($h_0$) by $h_0$ mod 7 where 0 = Saturday, 1 = Sunday, and so on.
3) The (preliminary) lunar date of the solar new year. Using the New year *ahargana*, $h_0$, the number of elapsed *tithis*, $t_0$, is computed by the following formula:

$$t_0 = (h_0 \times 703 + 650)/693 \qquad (10)$$

Then the *tithi* of the solar New Year is given by $t_1 = t_0 \bmod 30$. If $t_1 < 6$ the date will be in *Vaisakha*, the second lunar month; otherwise in *Caitra*, the first lunar month. $t_1 = 0$ is replaced by $t_1 = 1$ (*Vaisakha*). (A very rare exception is that if the *avoman* is equal to 692, $t_1$ should be diminished by one.).

Counting backwards from the solar New Year weekday it is now easy to find the weekday, $W$, of 1 *Caitra* , the beginning of the lunar year. Depending on the type of year the weekday of the start of the next lunar year, $W_{next}$ can be calculated:

1) For a normal year by $(W + 4) \bmod 7$, ($354 \bmod 7 = 4$).
2) For a year with an intercalary day by $(W + 5) \bmod 7$, ($355 \bmod 7 = 5$).
3) For a year with an intercalary month (by $(W + 6) \bmod 7$, ($384 \bmod 7 = 6$). A year with both an intercalary day and month is treated as one with only an intercalary month, the intercalary day not being inserted but kept in waiting.

As an example, we look at a sequence of the years 20–39 in the Chulasakarat era and get Table 6.

The requirement for an uninterrupted flow of weekdays is that $W_{next}$ of any year should be equal to $W$ of the following year. In year 22 and 38 we need to move the whole lunar year back one day in order to achieve this. This will also cause the solar new year date to move one day forward in the lunar calendar. It is called "exception One" by Faraut (1910: 121). For year 22 this shows a case when the solar year will start on 6 *Vaisakha*, the date being pushed from 5 *Vaisakha*.

There are two instances of intercalary years, 30 and 35, where it is necessary to move the extra day to one of the adjacent years. For year 30 it is seen that by increasing $W_{next}$ in the previous year by one unit and thus making the year one day longer and moving the part of the lunar year from 1 *Waso* to the end of the year on step

Table 6: Intercalary day allocation.

| Year | Type | $W$ | $W_{next}$ | $t_1$ |
|---|---|---|---|---|
| 20 | B | 0 | 5 | 13 |
| 21 | A | 5 | 2 | 23 |
| 22 | C | 3→2 | 2→1 | 5→6 |
| 23 | A | 1 | 5 | 16 |
| 24 | C | 5 | 4 | 27 |
| 25 | B | 4 | 2 | 8 |
| 26 | A | 2 | 6 | 19 |
| 27 | C | 6 | 5 | 1 |
| 28 | A | 5 | 2 | 11 |
| 29 | A | 2 | 6→0 | 22B |
| 30 | BC | 0 | 6 | 4 |
| 31 | A | 6 | 3 | 14 |
| 32 | C | 3 | 2 | 25 |
| 33 | A | 2 | 6 | 7 |
| 34 | A | 6 | 3 | 18 |
| 35 | BC | 3 | 2 | 29 |
| 36 | A | 3→2 | 0 | 9→10B |
| 37 | A | 0 | 4 | 21 |
| 38 | C | 5→4 | 4→3 | 2→3 |
| 39 | A | 3 | 0 | 13 |

Table 7: Intercalary vatriant allocation.

| Year | Type | $W$ | $W_{next}$ | $t_1$ |
|---|---|---|---|---|
| 20 | B | 0 | 5 | 13 |
| 21 | A | 5 | 2 | 23 |
| 22 | C | 3→2 | 2→1 | 5→6 |
| 23 | A | 1 | 5 | 16 |
| 24 | C | 5 | 4 | 27 |
| 25 | B | 4 | 2 | 8 |
| 26 | A | 2 | 6 | 19 |
| 27 | C | 6 | 5 | 1 |
| 28 | A | 5 | 2 | 11 |
| 29 | A | 2 | 6 | 22 |
| 30 | BC | 0→6 | 6→5 | 4→5 |
| 31 | A | 6→5 | 3 | 14→15B |
| 32 | C | 3 | 2 | 25 |
| 33 | A | 2 | 6 | 7 |
| 34 | A | 6 | 3 | 18 |
| 35 | BC | 3 | 2 | 29 |
| 36 | A | 3→2 | 0 | 9→10B |
| 37 | A | 0 | 4 | 21 |
| 38 | C | 5→4 | 4→3 | 2→3 |
| 39 | A | 3 | 0 | 13 |

forward, the extra day can fit into that year as an intercalary day 30 in the month of *Nayon* and the flow of weekdays will be restored.

For year 35 the following year could start one day earlier making room for the extra day and again restore the flow of weekdays. This will move the part of the lunar year from the start to the end of the third month, *Nayon*, where the extra day will be inserted and thus also move the lunar date of the solar new year one day forward in the lunar calendar.

Note, however, that the extra day could also have been accommodated in the year following year 30 by changing $W$ of year 31 from 6 to 5 and moving the $W$ and $W_{next}$ of year 30 one step down and the solar new year lunar date of that year one step up (Table 7). This could implement an alternative rule of always inserting the intercalary day in the following year. In a similar way the extra day in year 35 can be inserted in the previous year. These are possible solutions of the intercalation problem but require more shifts.

## 6.3 Glossary

*adhikamasa* An indication as to whether or not a given year has an intercalary lunar month in it. Intercalary months are used to ensure that the lunar calendar keeps in step with the solar one. In Thai it is *adhikamat* (อธิกมาส).

*adhikavara* An indication as to whether or not a given year has an intercalary day in it. Intercalary days are used to ensure that the lunar calendar keeps in step with the (mean) Moon. In Thai it is *adhikawan* (อธิกวาร).

*ahargana* The number of elapsed days since the epoch.

*Anchansakarat era* One of the eras used in Thailand with epoch 10 March 691 BCE.

*Arakanese Calendar* A calendar used in Arakan. It is similar to the *Makarata* Calendar and having the same epoch 22 March 638 CE. Instead of doubling Waso in an intercalary year, the *Arakanese* calendar doubles the first month Tagu.

*avoman* Thai อวมาน, Burmese အဝမာန်. The excess of lunar days over solar days in units of 1/692 of a lunar day modulus 692. It increases by 11 units each solar day. It is used to determine when to add intercalary days in the calendar. Sometimes in Burmese astronomy the avoman is expressed in units of 1/703 of a solar day.

*bath* Thai (บาท). A Thai time unit equal to ¼ *nadi* or 15 *vinadi*.

*bizana* Burmese ဗိဇနာ. See *vinadi*.

*Buddhasakarat era* One of the eras used in Thailand. The epoch is 11 March 544 BCE.

*Burmese Era* The epoch of the Burmese Era is identical with the Thai *ahargana, t*he number of elapsed days since the epoch CE 22 March 638.

*haragon* Burmese term for *ahargana*. The term *tawana* is used more often.

*horakhun* Thai หรคุณ. See *ahargana*.

*kammacabala* Thai (กัมมัชผล). A quantity that gives the excess of solar days over whole solar days.

*kromatopo*l Khmer term for Thai *kammacabala.*

*kyammat* Burmese ကမ္မြတ်. See *kammacabala*.

*Mahasakarat era* An era used in Thailand. Its epoch is the same as the *Śaka era*, CE 17 March 78.

*masaken* Thai มาสเกณฑ์. In Burma the term *sandyamat* (စန္ဒမြာယ)is used. The number of elapsed lunar months since the epoch.

*modulus* A mathematical operation on an integer where an integer is divided by another integer and the modulus is the remainder.

*nadi* An Indian time measure with 60 *nadi* in a day and night. In Thai it is *nathi* and in Burmese *nayi*. It corresponds to 24 minutes.

*nakṣatra* A measure of the Moon's longitude where the zodiac is divided into 27 parts, each covering 13° 20′. In Thai it is called *rœk* and in Burmese *nekkhat*.

*Pagan Kingdom* The first kingdom to unify the regions that would later be the present-day Burma. From around the ninth century it expanded from settlements at Pagan. At the end of CE 1200 it was subject to several Mongol invasions.

*nalika* Thai time unit corresponding to 60 minutes.

*nathi* Thai นาที. See *nadi*.

*nayi* Burmese နာရီ. Se *nadi*.

*nekkhat* Burmese နက္ခတ်. See *nakṣatra.*

*nyepi* The Balinese New Year day, the first day of month 10, Kadasa.

*pada* Thai time unit corresponding to 6 minutes.

*roek* Thai ฤกษ์. See *nakṣatra.*

*Romakasiddhānta* An Indian astronomical canon characterised by being the only Indian canon using Metonic intercalation.

*Śaka era* An Indian era with epoch CE 17 March 78. See *Mahasakarat era*.

*Songkran* Thai สงกรานต์ from Sanskrit *sankranti*. Strictly, *Songkran* is the time when the Sun passes from any one sign to another, but the word is used more particularly in connection with its passage from Pisces to Aries (*mahasongkran*). The precise time of *Songkran* is when the True Sun has a longitude of 0. See further under *thalœngsok.*

*suryayatri* A set of computational rules for the Thai calendar based on the rules of the original *Sūryasiddhānta* albeit in a slightly simplified version.

*thalœngsok* Thai เถลิงศก. More generally a word defining the start of an era; but used by astrologers to refer to the time when the Sun's mean longitude reaches 0°. This moment defines the end of the New Year festival period.

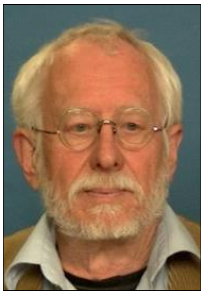
*uccabala* A measure of the position of the Moon's apogee. It increases by one unit a day to a maximum of 3232.

*vinadi* An Indian time measure being 1/60th of a *nadi*.

*wan-gyi-tat* Burmese ဝါငယ်ထပ်. A Burmese lunar year with an intercalated month and an intercalated day.

*wan-ngè-tat* Burmese ဝါကြီးထပ်. A Burmese lunar year with an intercalated month.

*yoga* An artificial quantity being the sum of the longitudes of the Sun and the Moon. It is expressed as the possible 360° divided into 27 parts, each spanning 13° 20′. There are dozens of other kinds of *yoga*, but very little assistance is given by the handbooks as to how they are determined.



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**Dr Chris Eade** has an MA from St Andrews and a PhD from the Australian National University. In 1986 he retired from the Australian National University, where he had been a Research Officer in the Humanities Research Centre before moving to an affiliation with the Asian Studies Faculty, in order to pursue his interest in Southeast Asian calendrical systems. In particular, research that he continued after retirement concerned dating in Thai inscriptional records, in the horoscope records of the temples of Pagan and in the published records of Cambodia and Campa.

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# THE CALENDARS OF SOUTHEAST ASIA
# 3: VIETNAM

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**Abstract:** This paper discusses the causes of misunderstanding about the nature of Vietnamese calendars; about the ancient Vietnamese calendar-finding process; about the results of studying three old calendars that were produced by different Vietnamese dynasties; and about the differences that existed between Vietnamese and Chinese calendars when they existed simultaneously; and finally some consequences of studying these ancient Vietnamese calendars.

**Keywords:** History of astronomy, calendars, Vietnam

## 1 INTRODUCTION

This paper deals with ancient Vietnamese calendars that date between AD 1544 and 1903, that is to say from the Giap Thin (甲辰) year, which is the 12th Nguyên Hoa (元和) year of King Lê Trang Tông's (黎莊宗) reign in the Restored Lê Dynasty (黎中興), up to the Quy Mao (癸卯) year, which is the 15th Thành Thái (成泰) year of the Nguyễn (阮) Dynasty.[1]

### 1.1 A Brief History of Research on Ancient Vietnamese Calendars

In 1884, after the conclusion of the Giap Tuat (甲戌, Patenotre) Treaty, Vietnam was divided into three regions with different systems of Government: Tonkin (Bac Ky = Northern Vietnam), Annam (Trung Ky = Central Vietnam) and Cochinchina (Nam Ky = Southern Vietnam). In Tonkin (Northern Vietnam) and Cochinchina (Southern Vietnam), the needs of the administrations prompted the French to prepare comparative calendars in French and Quoc ngu (a native script) that matched the solar and the lunar-solar calendars.

The first of these French calendar-makers was Raymond Deloustal (1872–1933) from the French colonial service, who produced his *Annamite-French Calendar from 1802 to 1922*. This was published in 1908 (Deloustal, 1908) and was republished in 1915 and 1922. The cover of one of these calendars is shown in Figure 1. Cordier and Le Duc Hoat (1935) were next to produce a calendar, with their *Concordance of Lunar and Solar Calendars from 1802 à 2010* (Figure 2). All three authors based their works on the Chinese calendar as described in a book by Hoang (1910) titled *Concordance des Chronologies Neoméniques Chinoise et Européene.* Unfortunately, they did not contact the Observatory in Annam (Central Vietnam) and wrongly assumed that Vietnam used the Chinese calendar.[2] They were unaware that in Annam (Central Vietnam), the *Kham Thien Giam* (Observatory) of the Nguyễn Dynasty produced a lunar-solar calendar of its own to be used in Vietnam, and that the King distributed this

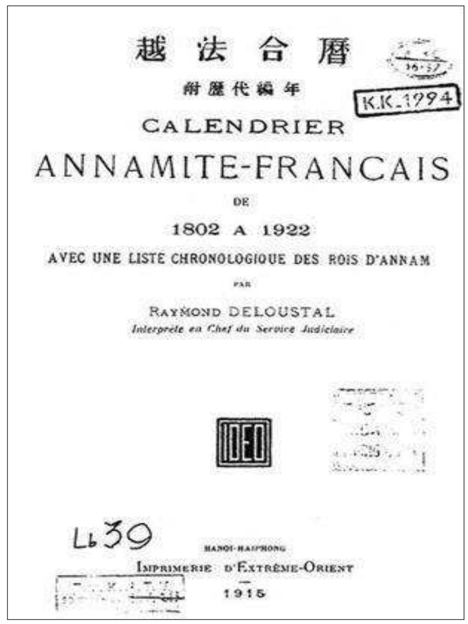



Figure 1: The cover of Deloustal's Calendar.


Figure 2: The cover of Cordier and Le Duc Hoat's Calendar.

Table 1: The intercalary moons in the Deloustal, Cordier and Le Duc Hoat, and Vietnamese calendars.

| Year | | Cordier and Deloustal's Calendar | | Vietnamese Calendar | |
|---|---|---|---|---|---|
| Lunar Calendar | Solar Calendar | Name Moon | Order Moon | Name Moon | Order Moon |
| 癸亥 | 1803 | 2 | 3rd | 1 | 2nd |
| 乙丑 | 1905 | 6 | 7th | 8 | 9th |
| 戊辰 | 1808 | 5 | 6th | 6 | 7th |
| 辛未 | 1811 | 3 | 4th | 2 | 3rd |

calendar every year. As the Chinese Han script was gradually replaced by the Quoc ngu, and the above-mentioned calendars became quite prevalent, this misconception was deeply embedded in the minds not only of foreigners but also of Vietnamese people. The calendar for the first eleven years of the Nguyễn Dynasty (1802–1812) by these authors was obviously based on the Chinese calendar (see Table 1 and Figures 3 and 4). However, during this eleven-year period there are four major differences between the Deloustal and the Cordier and Le Duc Hoat calendars and the Nguyễn Dynasty calendar (see Table 1 and Figures 3–5): differences in the intercalary Moon; the lunar leap year has 13 lunar months; the intercalary Moon is named after the previous Moon; and regarding the order, it will be increased by 1 (see Table 1).

In 1944, Hoàng Xuân Hãn examined a handwritten copy of the old *Bách trúng kinh Calendar* (百中經, *The Completely Accurate Calendar*). Coded A 2872, this was the Vietnamese calendar from 1624 to 1799. Hoàng Xuân Hãn declared that this Vietnamese Lê Dynasty calendar was quite different from the Chinese Qing Dynasty (清) calendar. Unfortunately, this hand-written copy of the *Bách trúng kinh Calendar* then disappeared, but people did not pay attention to Hoàng Xuân Hãn's comments because they were busy with the war against the French.

Then in 1982, in his book *Lịch và lịch Việt Nam* (*Calendars and the Calendar*), this same scholar (Hãn, 1982) examined the calendar of the Restored Lê Dynasty, covering the period 1644–1788, as well as a calendar of the early Nguyễn Dynasty, from 1802 to 1812. After accessing additional historical documents from the two countries he argued that there were substantial differences between the Vietnamese and the Chinese calendars during the Lý (李) and Trần (陳) Dynasties from 1080 to 1300. However, this was mere scientific speculation and not the result of research based on these early calendars, so his conclusion was not widely accepted.

Recently, as a result of our examination of three old calendars, we have been able to confirm the existence of an ancient Vietnamese calendar.

In 1967, Tùng et al.—who compiled the calendar for the Vietnamese Meteorological Service—read the book titled *Hoàng triều Minh Mệnh Khâm định vạn niên thư* (皇朝明命欽定萬年書, *Calendar of Thousands of Years Issued by King Minh Mệnh*), that includes the Vietnamese calendar from 1544 to 1861. However, they did not realize that this was specifically a Vietnamese calendar and therefore different from the Chinese calendar. Hence, they missed a chance to find an earlier ancient

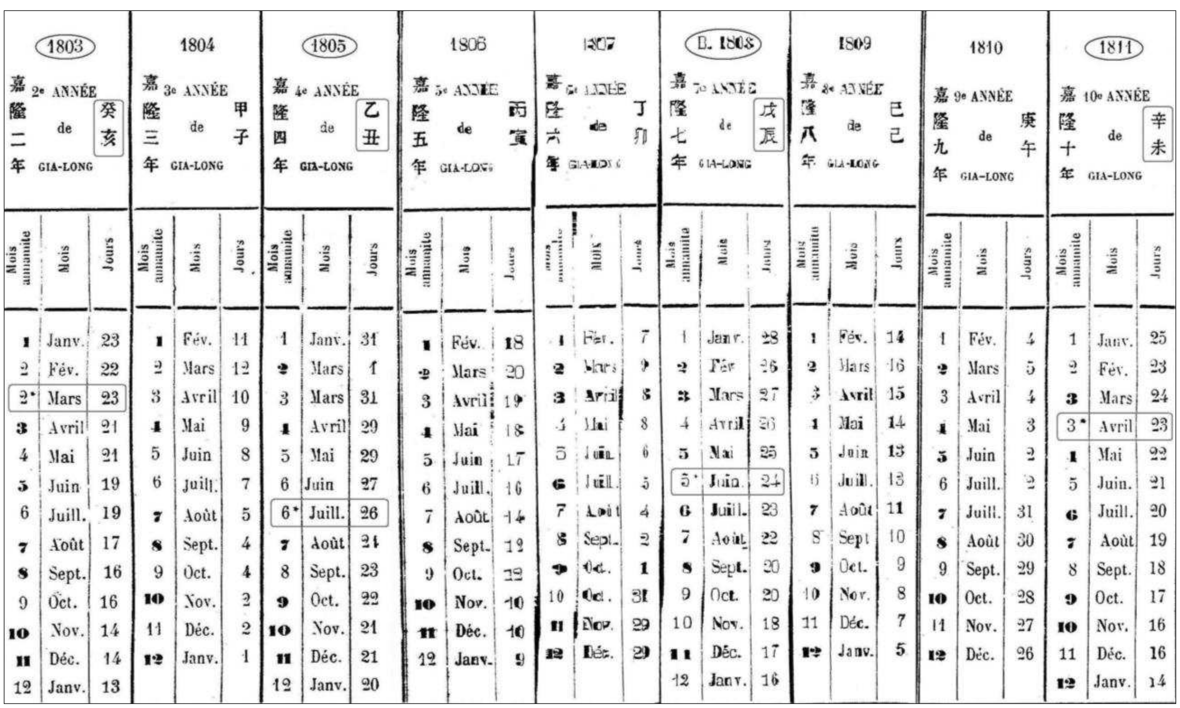



Figure 3: The intercalary moons from 1803 to 1811 in Deloustal's calendar.

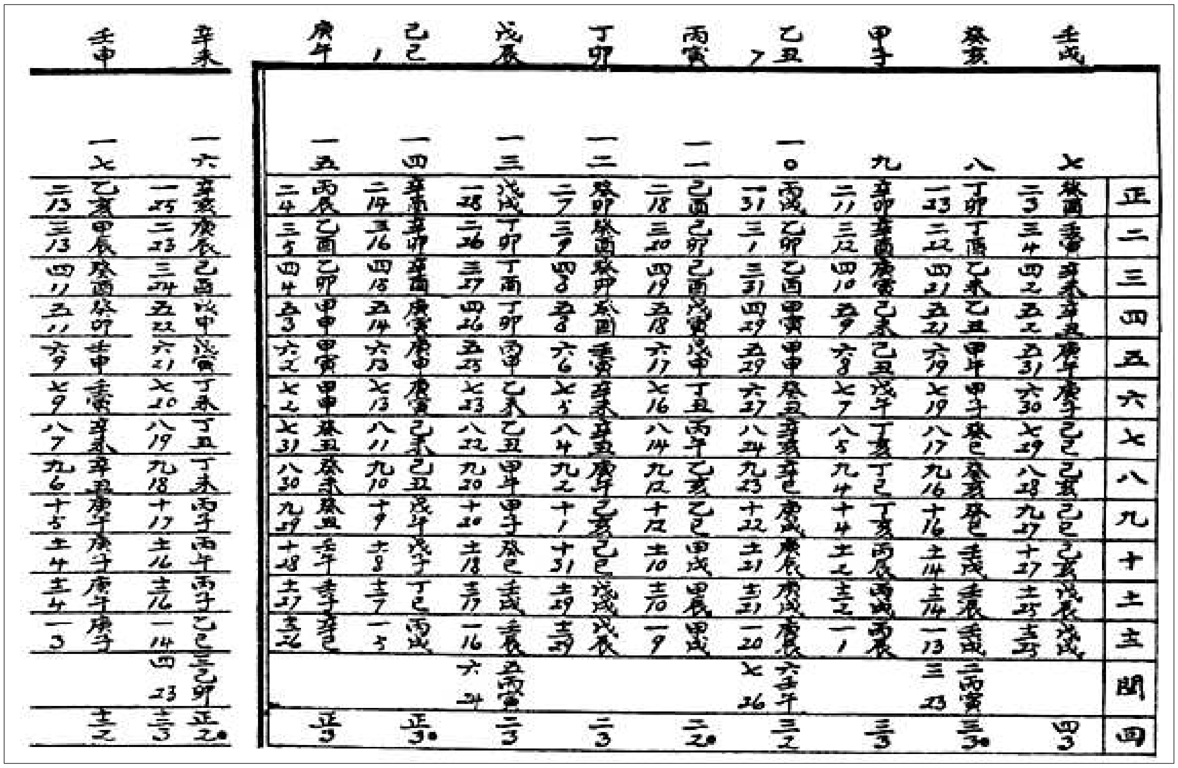


Figure 4: The Chinese calendar mentioned in 二十 史 朔 闰 表 by 陳垣 (1962) that also was used in the calendars by Deloustal and Cordier and Le Duc Hoat.

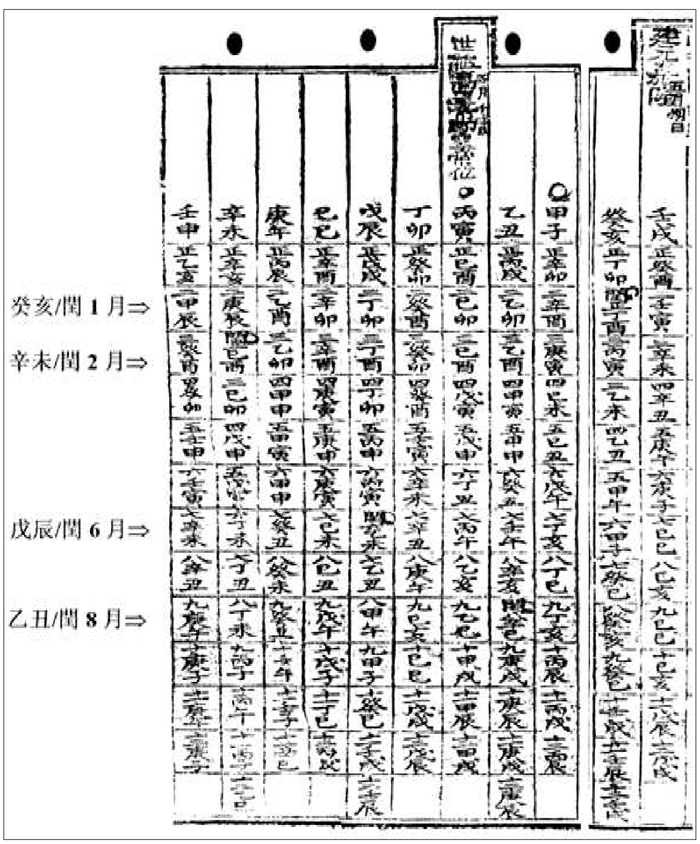



Figure 5: The Vietnamese calendar produced by the Nguyễn Dynasty Observatory. Key: the black ellipses mark the leap years that had 13 moons, and the arrows on the left indicate intercalary moons.

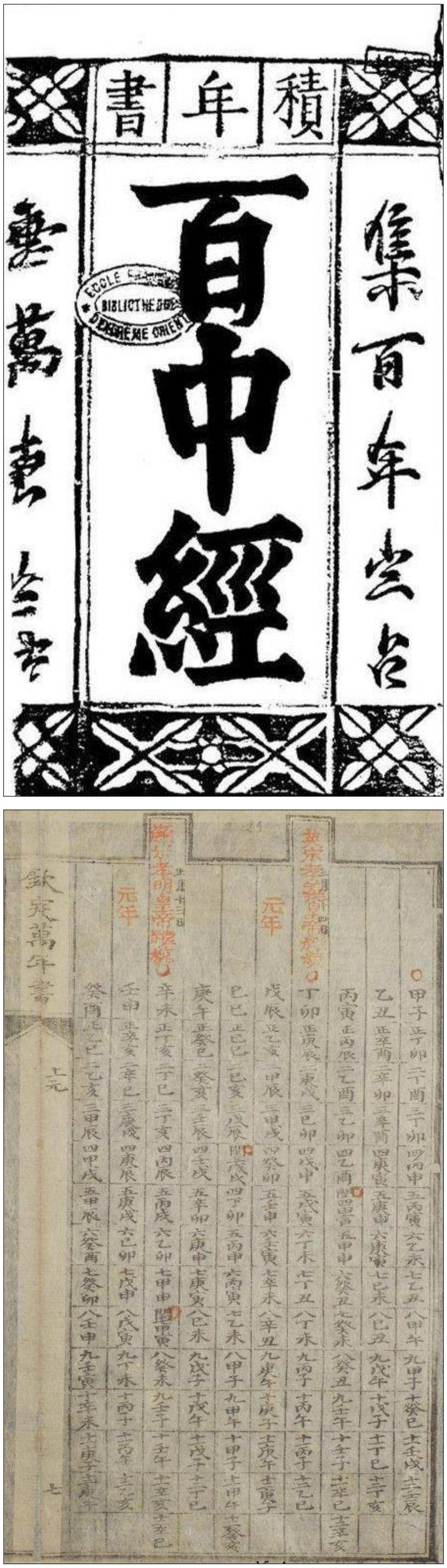



Figure 6: Two examples of Vietnamese calendars that were printed with woodblocks.'

Vietnamese calendar. Regrettably, the above-mentioned book is now lost.

In 1976, in the Preface of the book *Tables of the Collated Lunar and Solar Calendars and Historical Chronology for 2000 Years* (Bỉnh, Linh and Nghị, 1976; our English translation), Nguyễn Linh wrote about the *Bách trúng kinh Calendar* as a printed calendar of the Lê Dynasty. However, the author of *Tables* …, Nguyễn Trọng Bỉnh, was unaware of the *Bách trúng kinh Calendar* and therefore he did not consult it. His book only refers to the Chinese calendar, and so he missed the chance to investigate an ancient Vietnamese calendar.

In 1984 Lân (1986b) examined a copy of the *Bách trúng kinh Calendar* (n.d.), coded A3873, which had been printed in 1850. This Vietnamese calendar spanned the period 1624–1785, and was compiled by the Observatory of the Lê Dynasty. The calendar (see Figure 6) was printed with woodblocks and has survived through to the present day. Thus, it is an irreplaceable heritage object and an invaluable research tool. We presume that it was a version of this same *Calendar* printed using woodblocks that Hoàng Xuân Hãn examined back in 1944, and so its existence finally was confirmed.

The results of an examination of this ancient *Calendar* were then announced in two research papers (Lân, 1986b, 1987a). Fortunately, a photographic copy of the *Bách trúng kinh Calendar* was included in the book *Calendars for Five Hundred Years of Vietnam (1544–2043)* (Lân, 2010: 777–948), so it is now in the public domain and is freely available to scholars.

In 1993 Lân read the book *Khâm định vạn niên thư* (欽定萬年書; *Calendar of Thousands of Years Issued by the King*) which was compiled by the Observatory of the Nguyễn Dynasty in 1849 or 1850 and was printed from wood-blocks in two colors (see Figure 6). This book includes the calendar of the Restored Lê Dynasty from 1544 to 1630, the calendar of the Nguyễn Lords in Cochinchina from 1631 to 1801 and the calendar of the Nguyễn Dynasty from 1802 to 1903, so it collectively spans 360 years. Results of an investigation of this book were published in two papers (Lân, 1994a, 1994b), and a photographic copy of these calendars was included in *Calendars for Five Hundred Years* … (Lân, 2010: 950–999).

The *Khâm định vạn niên thư* book was only available in 1993 because initially it was included in a consignment of precious books that had been removed from the National Library and placed in a safe hiding place in case the Frontier War expanded to Hanoi. These precious books were only returned to the National Library in the early 1990s. When we found the book listed in the

Library catalogue, we did not expect that it would be important, especially knowing that a book with a similar title, *Hoàng triều Minh Mệnh Khâm định vạn niên thư*, had been mentioned by calendar-researchers in 1967, but this did not contain anything about ancient Vietnamese calendars.

These two calendars mentioned above provide irrefutable evidence that an ancient Vietnamese calendar existed that was different from the Chinese calendar.

In 1987 Lân began researching the handwritten book *Lịch đại niên kỷ bách trúng kinh* (歷代年紀百中經, *The Completely Accurate Calendar of Many Dignit- aries*, n.d., b), which contained calendars from the Restored Lê (1740–1788) and the Tây Sơn (西山, 1789–1801) Dynasties, a calendar from 1802 to 1812 based on the Đại Thống (大統) method, and 71 years of the calendar from the Nguyễn Dynasty (1813–1883). Initial results of the investigation were published in Lân (1987b). *Lịch đại niên kỷ bách trúng kinh* is especially important and valuable because it is the only document that shows the calendar from the Tây Sơn Dynasty (1789–1801), and it also includes calendars from the Nguyễn Dynasty, especially for the years 1850–1883 that *Khâm định vạn niên thư* only provided a preliminary draft calendar of, without any historical characteristics.

Because the *Lịch đại niên kỷ bách trúng kinh* was handwritten, it contains 76 errors, and we used an error-correction code to correct them. We then included photocopies of some of the important pages in the *Calendar for Five Hundred Years …* (Lân, 2010). In this book, pages 947–949 show calendars from the Restored Lê Dynasty for the period 1786–1788; pages 1000–1014 calendars from the Tây Sơn Dynasty for the years 1789–1801; and pages 1115–1118 the calendars from the Nguyễn Dynasty for the years 1849, 1856, 1866 and 1869.

In these three Vietnamese calendars, any book named *Bách trúng kinh* is the same as *Lịch đại niên kỷ bách trúng kinh* (曆代年紀百中經; n.d., b), and although written or printed at different times they were used contemporaneously. All of them have the three characteristics of a calendar: they are scientific, legitimate and historical. Meanwhile, the book named *Vạn niên thư* (萬年書) is identical to the books *Khâm định vạn niên thư* (1849 or 1850) and *Hoàng triều Minh Mệnh Khâm định vạn niên thư*, which usually has two quite different sections: the first contains a recorded calendar of years (thus in book R2200 it is from 1544 to 1850). The second section, from 1851 to 1883, has only a preliminary draft calendar for each year, so although based upon computations it cannot automatically be relied upon.

The study of the text of ancient calendars is an important task, but is very difficult as it requires meticulousness. What needs to done includes identifying: the author (the person or the compiling agency); the person who actually wrote the calendar (if it was not the author); the years in which the calendar was written, printed and subsequently copied; and any defective copying or printing errors (which must then be corrected and compared with the original). The corrected calendar must then be compared with the Chinese calendar and any differences noted. The calendar should then be searched for evidence of different historical events, and any information that expands on or explains the historical account, and particularly its dating, should be noted. This is demanding work and cannot always be carried out at the one time, especially if collaborators (who are hard to find) are required, so the work proceeds slowly. Another major difficulty is that scientific authorities do not show any interest in such projects, so are not keen to fund them. Thus, we have had to carry out most of our research independently.

## 2 A STUDY OF THE TEXTS OF THREE OLD VIETNAMESE CALENDARS

Calendars are like instruments that need to be absolutely accurate. It is therefore necessary to develop rigid scientifically-based methods for the revision of these old calendars. In this paper we use error-correcting code rules[3] to design mathematical formulae in accordance with congruence mathematics that can be used to detect possible remaining errors and fix them.

The more 'signals' a calendar has,[4] the more information redundancy it has, and therefore it is easier to detect any errors. Such a situation, however, often requires greater effort in checking the evaluation. In writing the lunar calendar, for example, two signals were used in the *Khâm định vạn niên thư*, five in the *Bách trúng kinh* and three in the *Lịch đại niên kỷ bách trúng kinh*.

### 2.1 *The Khâm định vạn niên thư*

This old calendar is now preserved in the National Library in Hanoi, and has the code R 2200.

#### 2.1.1 The Original Text

This calendar is very valuable since it was printed using woodblocks, except for the title on the cover "Tu Duc nguyen nien Mau Than trung thuyen". This title indicates that the woodblocks were carved in the first Tu Duc (嗣德) year, Mau Than 戊申, i.e. 1848). However, according to our research this is wrong, and R2200 actually was printed in Ky Dau (己酉; 1849) or Canh Tuat (更 戌; 1850).

This calendar was thoroughly studied before two papers were written about it (Lân, 1995, 1997c). According to the *Dateni Nam thuc luc* (大南寔錄, *Chronicle of Đại Nam*, 1963), the *Khâm định vạn niên thư Calendar* was compiled during the Nguyễn Dynasty, starting from the year 1820. It was carved on woodblocks, printed at least three times, and was revised each time. The first carving and printing was in the year Binh Than (丙申), 1836. As we have seen, the second printing (R 2200) took place in either the 1849 or 1850, not in 1848. The third printing occurred in the year Tan Dau (辛酉), 1861. R2200 is the only old Vietnamese calendar to be printed in two colors.

The idea of using mathematics to proof-read old calendars was first presented in Lân (2005), and was tested in Lân (2006b; cf. *Khâm định vạn* …, 1849 or 1850: 83–93; Lân, 1995b).

According to Lân (2006b; cf. Lân, 1997c), R2200 has three errors. Lunar months can only have 29 (hollow-小) or 30 (full-大) days, but we found in R2200 three violations of this rule:

- Month V in the year Binh Than (丙申, 1596) has 31 days. Possibly this is a carving error and can be corrected so that both months IV and V were full (30 days)—see Lân (1987a: 87–90, 965–966).
- Month X in the year Canh Thin (庚辰, 1880) has 41 days, whereas month XII has 17 days. Probably this needs to be revised so that each Moon is hollow (29 days)—see Lân (1987a: 90–91, 995–996).
- Month II in the year Giap Than (甲申, 1884) has 31 days. But according to the *Chronicle of Đại Nam* (1902, Volume XXXVI: 93), the historians still used this calendar, which means that an inaccurate calendar was in regular use. We have to accept this lack of accuracy (see Lân, 1987a: 91–92, 997–998).

### 2.1.2 Content

R 2200 consists of three parts:

(i) Part 1 covers a period of 97 years, from the year Giap Thin (甲辰, 1544) to the year Canh Ty (庚子, 1630), and is the calendar of the Restored Lê Dynasty. It may be regarded as the calendar of Le-Trinh or of The Tonkin (Northern Vietnam–Bac ha–北河).

(ii) Part 2 covers a period of 171 years, from the year Tan Suu (辛丑, 1631) to the year Tan Dau (辛酉, 1801), and is the calendar of the Nguyễn Lords of Cochinchina (Southern Vietnam–Nam ha–南河).

(iii) Part 3 covers a period of 102 years, from the year Nham Tuat (壬戌, 1802) to the year Quy Mao (癸卯, 1903), and is the calendar of the Nguyễn Dynasty. This Part has two sections. The first, covering 49 years from the year Nham Tuat (壬戌, 1802) to the year Canh Tuat (庚戌, 1850), meets the three current requirements for a calendar: it is scientific, it is legitimate and it is historical. The next section, covering 53 years, from the year Tan Hoi (辛亥, 1851) to the year Quy Mao (癸卯, 1903), was a calendar to be used as a preliminary draft for those years, and therefore only meets one of these calendar requirements: it is scientific. For this reason, one needs to consider it carefully. The first section has two subdivisions: the first 11 years, from the year Nham Tuat (壬戌, 1802) to the year Nham Than (壬申, 1812), is the calendar of the early Nguyễn Dynasty. Therefore, it was modelled on the Dai Thong (大統) calendar-making method and is quite distinct from the Chinese calendar (see Table 1 and Figure 2). The second sub-division covers the following 38 years, from the year Quy Dau (癸酉, 1813) to the year Canh Tuat (庚戌, 1850), and was modelled on the Thoi Hien (時憲) calendar-making method of the Chinese Qing Dynasty, and so it is very similar to the Chinese calendar.

R2200 includes the 80-year calendar of the Restored Lê Dynasty, from 1544 until the year Quy Hoi (癸亥, 1623), and continues into the period of the *Bách trúng kinh*, as we wrote in "A calendar of the Restored Lê Dynasty" (Lân and Dũng, 1995b). It also shows us the calendar of the Nguyễn Lords at Cochinchina (Lân and Dũng, 1995a). We are based in Hanoi and can only conduct our resarch part-time, so have not had a chance to carry out further fieldwork.

## 2.2 *Bách Trúng Kinh*

This old calendar (*Bách trúng tinh,* 1850) was found by the École Française d'Extrême-Orient (French School of the Far East), and is now preserved at the Institute of Han-Nom Studies in Hanoi, where it has the code A 2873.

According to the book list at the Han Nom Library, there are two books with the name *Bách trúng kinh*. The first is A2873 (a printed version) and the second is A2872, a hand-written version that contains a calendar from 1624 to 1799. Unfortunately, A2872 is now lost, but presumably this was the document that Hoàng Xuân Hãn saw and reported on in 1944.

A2873 contains a calendar for 160 years of the Restored Lê Dynasty, from 1624 to 1738. This was printed with woodblocks, but there is also a hand-written calendar that extends from 1739 to 1785.

### 2.2.1 The Original Text

The calendar is merely the calendar of the Restored Lê Dynasty, so it covers the period from the year Giap Ty (甲子, 1624) to the year Ky Ty (己巳,

1785). Due to a damaged page, the calendar for the two years At Mui (乙未, 1775) and Binh Than (丙申, 1776) is missing. The calendar therefore only spans 160 years.

The calendar for the period 1624–1738 is an invaluable historical document, but the calender for 1739–1785 is even more precious for it proves that these early calendars were originally handwritten.

The two calendars in A2873 contained three errors, which we discovered and corrected (Lân, 2006a; cf. 1987a: 76–77):

- Year Giáp Ngọ (甲午, 1714). In this year the woodblocks for the calendar were carved. Day 1 in month II was printed Quy Suu (癸丑), but has to be changed to Quy Dau (癸酉), to make month I hollow and month II full (Lân, 2006a; cf. Lân, 1987a: 77, 868–869).
- Year Mau Ngo (戊午, 1738). This is the last year that woodblocks for the calendar were carved. Day 1 in month X was printed Canh Tuat (庚戌), but has to be changed to Canh Thin (庚辰), so that month IX is full and month X is hollow (Lân, 2006a; cf. Lân, 1987a: 77, 893–894).
- Year Đinh Hoi (丁亥,1767). This year the calendar was handwritten. Day 1 in month VII was copied Quy Mao (癸卯), but must be changed to Quy Hoi (癸亥), in order to make month VI full and month VII hollow (Lân, 2006a; cf. Lân, 1987a: 78, 925–926).

#### 2.2.2 The Content

This calendar may be divided into two parts.

(i) This part was printed using woodblocks, and covers 115 years, from the year Giap Ty (甲子, 1624) to the year Mau Ngo (戊午, 1738). This part has very high historical value. Our research (see Lân, 1997d) revealed that the first woodblock carved for this calendar was possibly made in 1636, covering the first 12 years, from 1624 to 1635. Other carvings were made later, and not concurrently. The carving usually took place near the end of the preceding year, at the latest, before the year when the calendar was printed. For instance, the woodblocks for the calendar of 1738 were carved in the late 1737. This part of the calendar was perhaps printed after 1739, but not later than 1746, a fact which we learned from the book *Phuong Duc dang khoa luc* (鳳翼登稞錄) (Nhi, 1995) and *Vu toc the he su tich* (武族世系事迹) (Đinh, 2004). It is relatively certain that this calendar was printed and distributed widely by the Le-Trinh Royal Court.

(ii) This part was handwritten and it covers 45 years. The owner of the calendar perhaps wrote with his own hand the calendar for each succeeding year for the period from the year Ky Mui (己未, 1739) until the year At Ty (乙巳, 1785), when he was no longer able to complete the calendar for the last three years (1786–1788) of the Cảnh Hưng (景興) Dynasty.

On the last page, it is written: "Cảnh Hưng tứ thập thất niên tuế thứ Bính Ngọ" (Year of Binh Ngo (丙午), the 47th year of the Cảnh Hưng Dynasty (1786) (景 興 四 十七 年歲 次 丙午), but the owner of the book did not manage to copy the calendar of that year (Lân, 1987c: 945; 1997d).

The handwriting is not very fine, but it is easy to read.

### 2.3 *Lịch đại niên kỷ bách trúng kinh*

This old calendar also was found by the French École Française d'Extrême-Orient (i.e. French School of the Far East), and is now preserved at the Institute of Han-Nom Studies, where it has the code A1237.

#### 2.3.1 The Original Text

This calendar contains too many errors, so it is of low scientific value. According to our research results (Lân, 1987b, 2009), the A1237 calendar was hand written by the French School of the Far East during the period 1904–1907 from the *Trung dinh Lịch đại niên kỷ bách trúng kinh* (重訂歷代年紀百中經). Perhaps the latter was reproduced verbatim, just shortly after 1883, from four different calendars corresponding to the four parts that we will address below. Unfortunately, the *Trung dinh Lịch đại niên kỷ bách trúng kinh* no longer exists.

With respect to the A1237, this hand-written copy contains many errors and we had to use the error correcting-code method to correct these. In all we detected 76 errors, and we corrected 74 of them. For the two particular years, Mau Dan (戊寅, 1758) and Quy Suu (癸丑, 1793) there were just two major errors and we were unable to correct these (Lân 2007a, 2009). Meanwhile, the use of mathematics to correct the 74 errors is presented in the former research paper.

We discovered that the copier had inadvertently taken the calendar of the year Dinh Suu (丁丑, 1757) and wrote in place of it year Mau Dan (戊寅, 1758) and taken the calendar of the year Canh Tuat (庚戌, 1790) to put it into year Quy Suu (癸丑, 1793).

After making the 74 corrections we compared those parts of this calendar that also were preserved in other calendars and found that they were virtually identical. This gives us great confidence in the method of correction that we used and it also implies that those sections that were

not contained in other calendars were also reliable. On the whole, because A1237 was hand written we cannot insist on its legitimacy, but since it was copied by hand soon after 1883, it is indeed historical. Obviously it also is scientific, and it contains many parts that are very useful, particularly the sections from 1789 to 1801 (Lân, 2009) and from 1851 to 1883 when the calendars of the Tây Sơn Dynasty and the Nguyễn Dynasty respectively were in vogue.

### 2.3.2 Contents

This calendar consists of four parts.

(i) Part 1 covers 49 years of the reign of Lê-Trinh (黎-鄭) from the Restored Lê Dynasty, and extends from the year Canh Than (庚申, 1740) to the year Mau Than (戊申, 1788). After correction this part becomes totally identical with the calendar in the *Bách trúng kinh*.

We used this calendar for the two years 1775 and 1776 to replace the missing calendars in the *Bách krúng kinh* where the sheet was torn out. We also used the calendar for the three years, Binh Ngo (丙午, 1786), Dinh Mui (丁未, 1787) and Mau Than (戊申, 1788), for the last years of the Restored Lê Dynasty that 百中經 lacks.

(ii) Part 2 covers 13 years of the Tây Sơn Dynasty, from the year Ky Dau (己酉, 1789) to the year Tan Dau (辛酉, 1801). This is the most valuable part of the calendar since it is the only one that contains the calendar of the Tây Sơn Dynasty.

(iii) Part 3 covers 11 years, from the year Nham Tuat (壬戌, 1802) to the year Nham Than (壬申, 1812) This part was precisely constructed using the Dai Thong calendar method. In our opinion, this part is not from the calendar that was circulated during the Nguyễn Dynasty. It was probably prepared by officials from the Tu thien giam (司天監, Observatory) of the Lê Dynasty for use afterwards, and the person who copied the *Trung Dinh Lịch đại niên kỷ bách trúng kinh* erroneously recopied it. Probably when Phan Thuc Truc (潘叔直) came to the North, he also made use of this *Tu thien giam* (司天監) *Calendar* when writing his *Quoc Su Di Bien* (國史遺編) (Phan, 1973). We will discuss this in more detail on another occasion.

(iv) Part 4 covers 71 years, and should be divided into two sub-sections. The first of these covers 38 years, from the year Quy Dau (癸酉, 1813) to the year Canh Tuat (庚戌, 1850). After correction this part is identical to the calendar in the *Khâm định vạn niên thư*. The second sub-section, covering the period from the year Tan Hoi (辛亥, 1851) to the year Quy Mui (癸未, 1883), differs in three instances from the calendar in the *Khâm định vạn niên thư*. Due to its historical characters, this calendar was used contemporaneously. This can be confirmed by studying of a few events described in the *Chronicle of Đại Nam* (Quốc sử quán Thế kỷ 19, 1963), as briefly discussed in Lân (1987b, 2009) and addressed in more detail in Lân (1997d).

Calendars for the five years At Mui (乙未, 1775), Binh Than (丙申, 1776), Binh Ngo (丙午, 1786), Dinh Mui (丁未, 1787) and Mau Than (戊申, 1788) in the book *Lịch đại niên kỷ bách trúng kinh* (Lân, 1987a: 947–949) were used to complement the calendar for those years lost or missing in the *Bách trúng kinh Calendar* (n.d., a) so that we now have a complete calendar for all years through to the end of the Lê Dynasty.

The calendar from the year Ky Dau (己酉, 1789) to the year Tan Dau (辛酉, 1801) is the calendar of the Tây Sơn Dynasty (see Lân, 2010: 1003–1014).

Calendars for the years Ky Dau (己酉, 1849), Binh Thin (丙辰, 1856), Binh Dan (丙寅, 1866) and Ky Ti (己巳, 1869) were used during the Nguyễn Dynasty (Lân, 2010: 1015–1018) whereas the calendar for these years in the *Khâm định vạn niên thư* was not used because it was not always reliable, and therefore does not satisfy the historical calendar requirement.

The research on this particular calendar was much more meticulous and difficult compared to the two other calendars mentioned above. Currently we do not have the conditions or facilities to complete this research, or to publish the calendar after it has been proofread and corrected. This is regrettable because we only were able to publish a small number of pages from this calendar in *Calendar for Five Hundred Years …* (see Lân, 2010: 947–949, 1003–1018).

## 3 VIETNAMESE ANCIENT CALENDARS

In comparing the calendars, we pay attention to their differences according to three criteria:

(i) First is the 'soc' day (塑, the first day of a lunar calendar month), which is regarded as being a minor difference. The discrepancy is only one day between calendars, but it carries over the whole Moon.

(ii) Second is the intercalary Moon (閏月), which is regarded as a major difference. In this case the difference between the calendars continues over many Moons, and even the name of the Moons also differ.

(iii) Third is the Tet (春節, New Year, the New Year's Day of the lunar calendar); this is a fact

of special interest and is regarded as an extreme difference.

In some instances, the differences that occurred related to two different criteria.

With the three ancient calendars mentioned above we have been able to reconstruct Vietnamese calendars from 1544 through to the present day. A summary of the main finding is given below.

## 3.1 The Periods of Newly Regained Independence

While it was under Chinese domination of course Vietnam used the Chinese calendar. However, when Vietnam regained its independence during the Ngô (吳, 939–968), Đinh (丁, 968–980) and Tiên Lê (前黎, 980–1009) Dynasties and the first years of the Lý Dynasty these were short intervals and officials were busy establishing and strengthening the Government, so they did not pay attention to calendrical calculations. Consequently, people continued to use the Chinese calendar.

## 3.2 The Lý and Trân Dynasties

Hoàng Xuân Hãn studied ancient documents such as the *Abridged Chronicles of Dai Viet* (大越史略), the *Complete Annals of Dai Viet* (大越史記全書), *Thien uyen tap anh* (禪苑集英), etc. in order to find the dates of historical events and compare them with those listed in the Chinese calendar. He found intercalary lunar months (intercalary Moon) or hollow Moon (29 days) and full Moon (30 days) different from those in the Chinese calendar and included them in a table in his *Calendar and Vietnamese Calendar* (Hân, 1982, my English translation). We took part of that table to create Table 2. From Table 2 we can see that the calendar of the Lý and Trân Dynasties (1080–1300) is markedly different from the Chinese calendar (with 11 differences). There are six major differences about the intercalary months (1–5, 13 in Table 2), two extremely large differences (both New Year and intercalary Moon; entries 6, 10) and three minor differences (the first day of the Moon; entries 8, 11 and 12).

According to research by Hoàng Xuân Hãn and by us, from AD 1080 Vietnam compiled a calendar that differed from the Chinese calendar, and these differences lasted until the end of the Nguyễn Dynasty in the twentieth century. Sometimes these differences were major, but at other times they were very minor. Unfortunately, we have yet to find a Vietnamese calendar from the period 1080–1543, so this issue is still not fully resolved.

## 3.3 The Calendar of the Restored Lê and the Waning Lê (末黎) Dynasties

This calendar covers 245 years during the Restored Lê and the Waning Lê (末黎) Dynasties,

Table 2: Differences between the Vietnamese and Chinese calendars.

| No | year 干支 | | year solar | Vietnamese Cal. Name intercalary moon | Vietnamese Cal. Literature | Chinese C. Name intercalary moon | Different types |
|---|---|---|---|---|---|---|---|
| 1 | Canh Thân | 庚申 | 1080 | 8 | VSL | 9 | Major |
| 2 | Giáp Thìn | 甲辰 | 1124 | 1 | TT | 3 | Major |
| 3 | Bính Ngọ | 丙午 | 1126 | 11 | TT | 11 | Major |
| 4 | Kỷ Dậu | 己酉 | 1129 | 8 | TT | 8 | Major |
| 5 | Nhâm Tý | 壬子 | 1132 | 5 | TT | 4 | Major |
| 6 | Ất Sửu | 乙丑 | 1145 | No | | 11 | Extremely |
| | Bính Dần | 丙寅 | 1146 | 6 | TT | No | |
| 7 | Tân Mùi | 辛未 | 1151 | 4 | TUTA | 4 | No |
| 8 | Canh Ngọ | 庚午/9 | 1210 | 9 hollow | TT | 9 full | Minor |
| 9 | Tân Mùi | 辛未 | 1211 | 2 | VSL | 2 | No |
| 10 | Bính Thân | 丙申 | 1256 | 3 | TT | No | Extremely |
| | Đinh Tị | 丁巳 | 1257 | No | | 4 | |
| 11 | Ất Dậu | 乙酉/2 | 1285 | 2 full | TT | 2 hollow | Minor |
| 12 | Đinh Hợi | 丁亥/12 | 1287 | 12 full | TT | 12 hollow | Minor |
| 13 | Canh Tý | 庚子 | 1300 | 3 | TT | 8 | Major |

**Key:**

Different Types: Minor for First day of Moon. Major for Intercalary Moons. Extreme differences for Intercalary Moons *and* New Year.

Literature: VSL for *Việt sử lược* (越史略);

TT for Đại *Việt sử ký toàn thư* (大越史記全書);

TUTA for *Thiền uyển tập anh* (禪苑集英).

Table 3: Differences between Vietnamese and Chinese calendars.

| Period | Dynasty | Diff. w. Chinese C. | | | |
|---|---|---|---|---|---|
| | | General | Minor | Major | New year |
| 1544-1788 | Restored Le | 89 | 63 | 34 | 11 |
| 1789-1801 | Tay Son | 3 | 3 | | |
| 1802-1812 | Nguyen | 4 | | 4 | |
| 1813-1903 | Nguyen | 4 | 4 | | |
| 1530-1801 | Chua Nguyen | 92 | 69 | 21 | 8 |

from the year Giap Thin (甲辰, 1544) to the year Mau Than (戊申, 1788), and its existence was announced in the book, *Calendar for Five Hundred Years of Vietnam …* (Lân, 2010: 133–380).

The calendar of this period is also found in all three above-mentioned ancient calendars. Those parts that are in accord in two of the three calendars are in general identical. Compared to the Chinese calendar, there were 89 differences for this period of 245 years, which included 63 minor differences (塑, first day of Moon days), 34 major differences (閏月, intercalary Moons) and 11 extreme differences (春節, New Year) (see Table 3). So, in the past there were many instances when

Figure 7: Calendars for the year 1621. a) the Restored Lê calendar; b) the Chinese calendar.

Vietnam and China did not celebrate the New Lunar Year on the same day, and we published the results of a comparison in Lân (1987a) and Lân and Dũng (1995b).

### 3.3.1 Further Discussion

According to Hoàng Xuân Hãn (1982), prior to 1644 both Vietnam and China adopted the Dai Thong calendar-making method, and so Vietnamese and Chinese calendars were similar. Our study of the book *Khâm định vạn niên thư* revealed that this assertion is not correct (Lân and Dũng, 1995b). The fact is, within 100 years, from the year Giap Thin (甲辰, 1544) to the year Quy Mao (癸卯, 1643), there were 12 differences between the two calendars, which included 11 minor disagreements and one major discrepancy (see Figure 7). The calendar of the Restored Lê Dynasty has three intercalary Moons, while the Chinese calendar has two, and there are three extreme diffrences. Looking at the ratio 100/245 years and the ratio 12/89 differences we see that, when using the same method of construction, the two calendars differed very little although there were clear differences nonetheless. This leads us to make an educated guess that from 1300 to 1543, although historical documents do not show a clear disparity between the Vietnamese and Chinese calendars, there must have been differences between the two, but these differences are perhaps small in number (Lân, 1987c). As we have yet to discover a Vietnamese calendar for this period, we cannot test this proposition.

## 3.4 The Calendar of the Tây Sơn Dynasty (1789–1801)

This calendar covers just 13 years, from the year Ky Dau (己酉, 1789) to the year Tan Dau (辛酉, 1801), and its existence was announced in the book *Calendar for Five Hundred Years* … (Lân, 2010: 381–395).

Otherwise, a calendar of the Tây Sơn Dynasty can only be found in the hand-written *Lịch đại niên kỷ bách trúng kinh* (n.d., b), which is quite reliable. Compared with the Chinese calendar, there were only three differences, all on 'soc' days, and therefore they are only minor (see Table 3). Hân (1982) asserts that the Tây Sơn calendar is a direct copy of the Chinese calendar, but much earlier, after studying the hand-written *Bách trúng kinh*, he had stated (Hãn, 1944) that the Tây Sơn calendar was only somewhat similar to the Chinese calendar. We believe that his 1944 assertion is correct, and in two different research papers (Lân and Dũng, 2003; Lân, 2014) we explain why Hân changed from a correct conclusion to an incorrect one.

The results of our research indicate that the Tây Sơn calendar is different from the Chinese

calendar. This conclusion is reached, thanks to the help of a sophisticated mathematical construction, making use of coding theory and the theory of mathematical congruence (see Lân, 2009). In our opinion, King Quang Trung (光中) had a local (Vietnamese) calendar made for his Dynasty. This is quite conceivable if we recall that from the Lý Dynasty, Vietnam already had its own calendar and in the later period the Nguyễn Lords in the Cochinchina also had their own calendar.

## 3.5 The Calendar of the Nguyễn Dynasty (1802–1903)

This calendar spans 102 years, from the year Nham Tuat (壬戌, 1802) to the year Quy Mao (癸卯, 1903), and was first announced in book *Calendar for Five Hundred Years …* (Lân, 2010: 396–543).

The calendar for this period is found in the *Khâm định vạn niên thư* (1849 or 1850) and the *Lịch đại niên kỷ bách trúng kinh* (n.d., b). For the purposes of our study, this period was divided into two sub-periods:

(i) The first period covers 11 years, from 1802 to the year Nham Than (壬申, 1812), during which the Nguyễn calendar adopted the Dai Thong calendar-making method while the Chinese Qing Dynasty used the Thoi Hien method. For this reason, although the period is short there were four differences between the two calendars. All of them were in intercalary Moons, and in each case the differences are major (see Tables 1 and 3 and Figure 2).

(ii) The second period covers 91 years, from the year Quy Dau (癸酉, 1813) to the year Quy Mao (癸卯, 1903). By then both countries used the Thoi Hien method of calendar-making so their calendars showed very little difference: there were only four differences, all in 'soc' days, and therefore only minor (see Table 3).

Preliminary research results were presented in Lân (1995c, 2000) and further details were provided in Lân (2007b, 2010).

## 3.6 The Calendar of the Nguyễn Lords of Cochinchina (1631–1801)

This calendar covers the 171 years from the year Tan Mui (辛未, 1631) to the year Tan Dau (辛酉, 1801). Initially Hoàng Xuân Hãn (1982) posed the question: Did the Nguyễn Lords have their own calendar? The answer was provided by the *Khâm định vạn niên thư* (1849 or 1850): yes they did.

This Southern Vietnamese calendar was printed in the *Khâm định vạn niên thư*, and differed from the Chinese calendar in 92 instances: 69 'soc' days (minor differences), 21 intercalary Moons (major differences) and eight Tets (extreme

Table 4: The differences between the calendars of Vietnamese Dynasties and the Nguyễn Lords.

| Period | Dynasty | D. w. Nguyen lords C | | | |
|---|---|---|---|---|---|
| | | General | Minor | Major | New year |
| 1631-1788 | Restored Le | 45 | 36 | 11 | 4 |
| 1789-1801 | Tay Son | 5 | 2 | 3 | 1 |

differences), as listed in Table 3.

In a period of 158 years, from 1631) to the year Mau Than (戊申, 1788), this calendar existed concurrently with the calendar from Le-Trinh's Restored Lê Dynasty from the Tonkin area in Northern Vietnam. These two calendars have 45 differences, including 36 'soc' days, 11 intercalary Moons and four Tets (see Table 4). So during this period there were times when the people living in the two regions of Vietnam did not celebrate Tet (New Year) on the same day (see Figure 5, where in the year Mau Ngo (戊午, 1678) all three calendars shown here were different).

For 13 years, from the year Ky Dau (己酉, 1789) until the year Tan Dau (辛酉, 1801), this calendar of the Nguyễn Lords existed concurrently with the Tây Sơn calendar. The two calendars differed in five instances: two 'soc' days, three intercalary Moons and one Tet (see Table 4). Therefore, the population living in the two overlapping administrations also did not celebrate Tet on the same day.

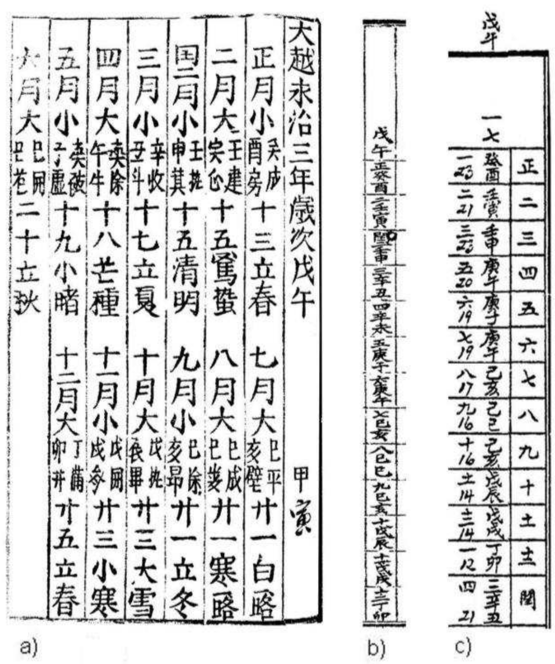



Figure 5: Three calendars for the year 1678. a) the Restored Lê Dynasty calendar; b) the Nguyễn Lords calendar; c) the Chinese calendar.

### 3.7 The Calendar of the Late Nguyễn Dynasty (1904 – 1945)

This calendar covers the period from the year Giap Thin (甲辰, 1904) to the year At Dau (乙酉, 1945. However, there are unresolved issues associated with this calendar, and although they are not major ones we will not discuss this calendar here.

### 3.8 Summary

The results of research published by Hoàng Xuân Hãn (1944, 1982) and those reached recently by us show that since AD 1080 Vietnam has always had its own calendar. In particular, we reconstructed the Vietnamese calendar dating from 1544, and we found that when the country was divided, for 171 years there were two different calendars that existed concurrently. We found that when Vietnam used a calendar-making method abandoned by the Chinese, the calendars of the two countries generally diverged from one another, but when the method used in Vietnam was the same as that adopted in China the two calendars differed very little.

## 4 HISTORICAL INFORMATION

### 4.1 Official Calendar Names

The Trân Dynasty had the *Thu Thoi Calendar* (授時), which later was changed to the *Hiep Ky Calendar* (协紀); the Ho Dynasty (胡) had the *Thuan Thien Calendar* (順天); the Lê Dynasty had the *Kham Thu Calendar* (欽授); the Nguyễn Lords had the *Van Toan Calendar* (萬全); and the Nguyễn Dynasty, in its early days, continued to use the *Van Toan Calendar*, and then adopted the *Hiep Ky Calendar*.

### 4.2 Calendar-making Offices

The Lau Chinh duong (正陽樓) was established during the Ly Dynasty; during the Lê Dynasty there was the Thai su vien (太史院); during the Restored Lê Dynasty there was the Tu thien giam (司天監); under the Nguyễn Lords there was the Chiem hau ty (占候司); and during the Nguyễn Dynasty there was Kham thien giam (欽天監).

### 4.3 Calendar-makers

Although they are rarely mentioned in the historical records, some individuals are known to have contributed to the construction of ancient Vietnamese calendars.

Hãn (1982) believes that at the beginning of the Lý Dynasty, the ambassadors Mai Canh Tien, Ly Ke Tien (1063) and Quach Si An, Dao Sung Nguyen (1069) may have had an opportunity to learn calendar-making from the Song Dynasty (宋). But at that time the Song Dynasty calendar-makers frequently changed their way of calculating calendars, whereas the Vietnamese calendar-makers did not do this, but instead often used methods no longer in vogue in China, which explains why between 1080 and 1300 the Vietnamese calendar differed markedly from the Chinese calendar.

In 1301, the King's envoy Đặng Nhữ Lâm returned from an audience with the Chinese Yuan (元) Imperial Court and brought with him a forbidden book, which probably dealt with the art of calendar-making. Lân (2013) has suggested that this may have led to the adoption of the Chinese method of calendar-making in Vietnam, so that the Vietnamese and Chinese calendars were similar.

Then in 1339, Đặng Lộ, a son of Đặng Nhữ Lâm, was appointed to the post of 'Hau nghi dai lang thai su cuc'. He was an expert calendar-maker, and he created a 'linh lung nghi' for the study of cosmic phenomena. It was he who suggested the conversion of *Thu Thoi Calendar* into the *Hiep Ky Calendar* (see Lân, 2011).

Near the end of the Trân Dynasty, Trân Nguyên Đán wrote the *Bach the thong ky* (百世通紀), a book dealing with the method of calendar making. Unfortunately this book has been lost, otherwise we would have been able to learn much about the Vietnamese calendar up to that time.

During the Nguyễn Dynasty, Nguyễn Hữu Thận also made a significant contribution to the creation of the Vietnamese calendar. In 1810 he led a Vietnamese delegation to the Chinese Qing Imperial Court, and brought back the *Lich tuong khao thanh* (曆象考成), a book dealing with the Thoi Hien calendar-making method of the Qing Dynasty. In 1812, he assumed additional responsbilities as Deputy Head of the Kham thien giam (Observatory). After that, the *Hiep Ky Calendar* of the Nguyễn Dynasty was modelled on the Thoi Hien method, so the Vietnamese and Chinese calendars were quite similar. It should be noted that the *Hiep Ky Calendar* that he proposed was in continuous use for 133 years, from 1813 to 1945. In 1816, King Gia Long said in praise of Nguyễn Hữu Thận:

> The art of calculation in the making of a calendar is extremely complicated, only Nguyen Huu Than is knowledgeable enough to be able to master it. (The Nineteenth Century National Historical Office, 1963; our English translation).

### 4.4 Dating Historical Events

Vietnamese calendars have been used to date some important historical events. For example, the date of entry into Đồng Hới (垌亥) by the Tây Sơn troops was 21 June 1786 (i.e. day 25 of the 5th Moon of the year Binh Ngo (丙午) (Lân, 1987c); and the date of Ngô Thì Nhậm's (吳時任) death (the day Tan Ti (辛巳) was 7 April 1803, that is

day 16 of the 2nd Moon of the year Quy Hoi (癸亥) (Lân, 1999). These calendars also have been used to establish the date of King Lý Bí's (李賁) death (Lân, 2006c); the hour and date when King Quang Trung (光中) died (Lân, 2006d); and the date when King Lý Thái Tổ (李太祖) ascended the throne (Lân, 1996b).

## 5 ESTABLISHING AN EXACT CHRONOLOGY FOR THE MẠC DYNASTY

A brief summary is provided above of some of the results of research on ancient Vietnamese calendars published in Lân (2000) and Lee (2010).

The first of these books (Lân, 2000) also presented Vietnamese and Chinese chronologies, and compared them. The method of presentation of these chronologies had several novel features: they were systematic, exact, used multiple criteria, and were easy to use (cf. Lân, 2016). But in particular, a new and exact chronology for the Mạc Dynasty (莫, 1533–1593) was reconstructed on the basis of epigraphical texts.

In our opinion, dates of contemporary events carved on stone are more reliable than those in historical records, particularly when these dates are combined together into a system. For this reason, Lân and Dũng (1999) and Lân (1997a) relied on 60 out of 148 epigraphical texts printed in the book *Đinh Khắc Thuân (sưu tầm, khảo cứu, dịch chú): Văn bia thời Mạc* (1996) and on 22 competitive examinations held during the Mạc Dynasty, as recorded in the book *Đăng khoa lục* (n.d., a), to construct a new and exact chronology for the Mạc Dynasty, until the end of the reign of Mac Mau Hop Hop (莫茂合). Lân (1997b) also observed that inscriptions on ceramics fully agreed with the epigraphical texts. This new chronology is completely different from the old one that was published by Bĩnh, Linh and Nghị (1976), and is similar to one that was produced by the Vietnamese Conservation Department (1970) and based on data in the *Ngô Sĩ Liên và các sử quan nhà Lê* (1993) for eight reigning years: Cảnh Lịch, Quang Bảo, Thuần Phúc, Sùng Khang, Diên Thành, Đoan Thái, Hưng Trị and Hồng Ninh (景曆, 光寶, 淳福, 崇康, 延成, 端泰, 興治, 洪寧; see Table 5 and Lân, 2016). In particular, the Thuan Phuc reigning years were recorded as 1562–1565 in the old chronology, which was wrong by three years. The correct date is 1565–1568, as given in the stone inscriptions (see Lân and Dũng, 1996; Lân, 2016: 46–47). This allowed us to argue that Lê Quý Đôn's *Đại Việt thông sử* (1978) provided the correct dates for the birth and the ascension to the throne of Mac Mau Hop whereas these dates as provided by the Ngô Sĩ Liên và các sử quan nhà were wrong. This was pointed out by Lân (1996a).

A host of chronologies relating to the Mạc Dynasty given by the *Ngô Sĩ Liên và các sử quan nhà Lê* (1993) and the *Quốc sử quán Thế kỷ XIX* (1957–1960) now need to be modified in order to conform to the correct chronologies. Initially, Lân (1998) proposed 53 modifications, and later he suggested 40 other modifications (Lân, 2002). These errors also exist in other works (e.g. Ngô, 1993, which has more than 150 errors—see Lân and Dũng, 1999).

It is a fact that historians of the Restored Lê Dynasty had a prejudice against the Mạc Dynasty, and therefore their writing on dates in the Mạc Dynasty was based on sloppy research and hence filled with errors. This prejudice against the Mạc Dynasty by the historians of the Restorred Lê Dynasty manifests itself most clearly in their failure to assign the Mạc Dynasty to a separate chapter in Ngô Sĩ Liên … (1993). This leads one to suspect that many of the historical events ascribed to the Mạc Dynasty by these historians are not necessarily reliable.

## 6 CONCLUSION

In this chapter we have summarized some of the research by Hoàng Xuân Hãn and ourselves on ancient Vietnamese calendars. We found clear evidence of such calendars from 1544 onwards,

Table 5: Duration of use of eight reigning years of the Mac Dynasty.

| Nr | Reigning years | | Duration for use | | New redefined day for use of reigning years |
|---|---|---|---|---|---|
| | | | Old | New | |
| 1 | Cảnh Lịch | 景曆 | 1548-1553 | 1548-1554 | 1st moon 1, 戊申 – 1548 |
| 2 | Quang Bảo | 光寶 | 1554-1561 | 1555-1564 | 1st moon 1 乙卯 – 1555 |
| 3 | Thuần Phúc | 淳福 | 1562-1565 | 1565-1568 | 1st moon, 1 乙丑 – 1565 |
| 4 | Sùng Khang | 崇康 | 1566-1577 | 1568-1578 | In year 戊辰 – 1568 |
| 5 | Diên Thành | 延成 | 1578-1585 | 1578-1585 | 7th moon 戊寅 – 1578 |
| 6 | Đoan Thái | 端泰 | 1586-1587 | 1585-1588 | 6th moon 28, 乙酉 – 1585 |
| 7 | Hưng Trị | 興治 | 1588-1590 | 1588-1591 | In year 戊子 – 1588 |
| 8 | Hồng Ninh | 洪寧 | 1591-1592 | 1591-1592 | In year 辛卯 – 1591 |

and during the period from 1631 to 1801 two different calendars coexisted. These results are promising, but the Vietnamese calendar from 1080 to 1543 has yet to be discovered, although during that period it definitely differed from the Chinese calendar.

As we wrote above, during the past decades two important calendars were lost, the hand-written *Bách trúng kinh* that Hoàng Xuân Hãn read in 1944 and the book *Hoàng triều Minh Mệnh Khâm định vạn niên thư*, which the compilers of the calendar for the Vietnamese Meteorological Service read sometime before 1967. At least the first of these books gave us the calendar of the year Quý Sửu (癸丑, 1793) during the Tây Sơn Dynasty which the *Lịch đại niên kỷ bách trúng kinh* incorrectly copied from another year. But the hand-written book *Lịch đại niên kỷ bách trúng kinh* has not been printed, so most scholars cannot easily read and study this calendar. There also are other calendars found in libraries (e.g. Lê Hữu Ích, n.d.), but we have not had an opportunity to research these yet. Nor have we ventured outside Hanoi to search for calandars that are stored in libraries and private collections within Vietnam and overseas. As such, ancient Vietnamese calendars still offer enormous opportunities for further research.[5]

## 7 NOTES

1. This paper is a slightly revised version of Lân and Nguyễn (2017). This is the third paper in a series on the historical calendars of Southeast Asia. The first paper (Gislén and Eade, 2019a) provides an introduction to the series, and the second paper (Gislén and Eade, 2019b) deals with the calendars of Burma, Thailand, Laos and Cambodia.
2. Nowadays, people tend to use the book 二十史朔闰表 by 陳垣 (1962), and we also use this book for our figures about the Chinese calendar that are reproduced in this Chapter (rather than using Hoang's book).
3. For an explanation of the error-correcting code rules, contact the first author of this paper.
4. 'Signals' are the length of the negative month, 10 stems, 12 branches, constellations and 'guardian stars'. Anyone interested in details of these signals and the ways in which they are used in Vietnamese calendrical analysis should contact the first author of this chapter.
5. Although this chapter has focussed primarily on our own research, based in Hanoi, and the work of a small number of other Vietnamese calendar-researchers, it is important to recognise that this topic also has attracted overseas scholars. For example, see Okazaki (2017).

## 8 REFERENCES

*Bách trúng kinh* (百中經). Coded A 2873 by the Library of the Institute for Han-Nom Studies (1850) (in Vietnamese).

Bỉnh, N.T., Linh, N., and Nghị, B.V. 1976. *Bảng đối chiến Âm Dương lịch 2000 năm và niên biểu lịch sử* (*Tables Comparing the Lunar Calendar with the Solar Calendar for 2000 Years and Historical Chronology*). Hanoi, Science of Society Publishing House (in Vietnamese).

Conservation Department, 1970. *Niên biểu Việt Nam* (*Vietnamese Chronology*). Hanoi, Social Sciences Publishing House (in Vietnamese).

Cordier, G., and Lê Đức Hoạt, 1935. *Concordance des Calendríers Lunaíre et Solaire de 1802–2010*. Ha noi, Imprimerie Chanphuong (in French).

*Đăng khoa lục* 登科錄. Coded VHV 650 by the Library of the Institute for Han-Nom Studies (n.d., a) (in Vietnamese).

Deloustal, R., 1908. *Calendner Annamite - Français de 1802 à 1916*. Haiphong, Imprimerie d'Extrême-Orient Hanoi (in French).

Đinh Danh Bá (丁名伯) (ed.), 2004. Vũ Thế Khôi (dịch và chí thích): *Vũ tộc thế hệ sự tích* (武族世系事迹). Hanoi, World Publishing House (in Vietnamese).

Đinh Khắc Thuân (sưu tầm, khảo cứu, dịch chú), 1996. *Văn bia thời Mạc* (*Epigraphic Texts of the Mac* (莫] *Dynasty*). Nxb Khoa học xã hội (in Vietnamese).

Gislén, L., and Eade, J.C., 2019a. The calendars of Southeast Asia. 1: Introduction. *Journal of Astronomical History and Heritage*, 22, 407–416.

Gislén, L., and Eade, J.C., 2019b. The calendars of Southeast Asia. 2: Burma, Thailand, Laos and Cambodia. *Journal of Astronomical History and Heritage*, 22, 417–430.

Hoang, P., 1962. *Concordance des Chronologies Néoméniques Chinoise et Européenne.* Changhai (in French).

Hoàng Xuân Hãn, 1944. Lịch và lịch đời Lê (Calendars and the calendar of the Lê Dynasty). *Thanh Nghị*, 51, 43-48, 57 (in Vietnamese).

Hoàng Xuân Hãn, 1982. *Lịch và lịch Việt Nam* (*Calendars and the Vietnamese Calendar*). *International Journal of Science in Society*, 1–110 [monograph] (in Vietnamese).

*Khâm định vạn niên thư* (欽定萬年書). Coded R 2200 by the National Library (1949 or 1950) (in Vietnamese).

Lê Hữu Ích (黎有益), n.d. *Thành Thái bách niên lịch* (成泰百年曆). Handwritten book, Han Hom Library (in Chinese).

Lân, T.L., 1986a. Nhìn lại những kết quả bước đầu trong việc nghiên cứu lịch Việt Nam (A review of the initial results of the research on the Vietnamese calendar). *Journal of Social Science Information*, 1, 59–70, 77 (in Vietnamese).

Lân, T.L., 1986b. Năm mới giở cuốn lịch cổ triều Lê (Reading the ancient calendar of the Lê Dynasty on the New Year occasion). *People's Newspaper*. Spring number of Bing Yin year (in Vietnamese).

Lân, T.L., 1987a. Lịch thời Lê – Trịnh (The calendar of the Le-Trinh Period). *Journal of Military History*. 21(9), 18–31 (in Vietnamese).

Lân, T.L., 1987b. Đọc và hiệu đính cuốn Lịch đại niên kỷ bách trúng kinh (Reading and correcting the book 歷代年紀百中經). *Journal of Han-Nom Studies*, 2(3), 40–48 (in Vietnamese).

Lân, T.L., 1987c. Lịch trình giải phóng Thuận Hoá của nghĩa quân Tây Sơn (The process of liberating Thuan Hoa by the Tây Sơn insurgent army). *Journal of Binh Tri Thien - Hue Historical Studies*, Nr. 1(10),

40–41 (in Vietnamese).
Lân, T.L., 1994a. Một di sản văn hoá quý báu. Cuốn lịch cổ Khâm đinh vạn niên thư (A precious cultural heritage object. An old time calendar 欽定萬年書). *Journal of Sciences and the Country*, 3, 27–28 (in Vietnamese).
Lân, T.L., 1994b. Hai cuốn lịch cổ vô cùng quý báu (Two extremely valuable ancient calendars). *Journal of Knowledge of Today*, 131(4), 65–68 (in Vietnamese).
Lân, T.L., 1995a. Một cuốn lịch cổ do Khâm thiên giám triều Nguyễn soạn và khắc in (An old calendar written and printed by the Kham thien giam (Observatory) of the Nguyễn Dynasty). *Journal of Hue Yesterday & Today*, 11, 49–54; 13, 48–51 (in Vietnamese).
Lân, T.L., 1995b. Tóm tắt việc giám định cuốn Khâm định vạn niên thư (A brief evaluation on the old calendar 欽定萬年書). In *New Archeological Finds in the Year 1994*. Hanoi, Institute of Archeology. Pp. 382–384 (in Vietnamese).
Lân, T.L., 1995c. *Lịch hai thế kỷ (1802–2010) và các lịch vĩnh cửu* (*Calendar of Two Centuries (1802–2010) and Perpetual Calendars*). Hanoi, Thuan Hoa Publishing House (in Vietnamese).
Lân, T.L., and Dũng, T.N., 1995a. Lịch chúa Nguyễn Đàng trong (The calendar of the Nguyễn Lords in Cochinchina). *Journal of Hue Yesterday & Today*, 16, 84–97 (in Vietnamese).
Lân, T.L., and Dũng, T.N., 1995b. Lịch thời Lê trung hưng (The calendar of the Restored Lê Dynasty). *Journal of Hue Yesterday & Today*, 14, 76–83 (in Vietnamese).
Lân, T.L., 1996a. Chào đời sau khi đã làm vua được 14 tháng? (Born 14 months after being on the Throne?). *Student Journal*, October, 8 (in Vietnamese).
Lân, T.L., 1996b. Lý Thái Tổ lên làm vua ngày nào? (On what day did Ly Thai assume the throne?). *Journal of Sciences and the Country*, 9, 25–26 (in Vietnamese).
Lân, T.L., and Dũng, T.N., 1996. Dùng văn bia để xác định lại một vài niên hiệu của nhà Mạc (Using inscriptions for the re-determination of some reign years in the Mac Dynasty). *Journal of Archaeological Studies*, 3, 79–96 (in Vietnamese).
Lân, T.L., 1997a. Niên biểu nhà Mạc (Historical chronol-ogy of the Mac Dynasty). *Journal of Han-Nom Studies*, 1(30), 22–33 (in Vietnamese).
Lân, T.L., 1997b. Về một vài niên đại của nhà Mạc qua các hiện vật khảo cổ học (On some reigning years of the Mac dynasty on the basis of archae-ological finds). In *Archeological New Finds in 1996*. Hanoi, Social Science Publishing House. Pp. 432–434 (in Vietnamese).
Lân T.L., 1997c. Về văn bản cuốn Khâm đinh vạn niên thư (On the text of 欽定萬年書). In *Bulletin of Han-Nom Studies in 1996*. Hanoi, Social Sciences Publishing House. Pp. 161–164 (in Vietnamese).
Lân, T.L., 1997d. Về văn bản cuốn Bách trúng kinh (On the text of 百中經). *Journal of Han-Nom Studies*, 2(31), 23–27 (in Vietnamese).
Lân, T.L., 1998. Một vài ghi chú về niên đại nhà Mạc cho bộ Đại Việt sử ký toàn thư (Some notes on dates in the Mac (莫) Dynasty for the *Complete Annals of Đại Việt* - 大越史記全書). In *Ngo Si Lien and Dai Viet su ky toan thu*. Hanoi, Political Country Publishing House. Pp. 230–247 (in Vietnamese).
Lân, T.L., 1999. Về ngày mất của Ngô Thì Nhậm (About the date of Ngo Thi Nham's death). In *Lịch sử, sự thật và sử học* (*History, Truth and Historical Science*). Hanoi, Journal of Yesterday & Today and Young Publishing House. Pp. 363–366 (in Vietnamese).
Lân, T.L., and Dũng, T.N., 1999. Tính lại niên hiệu các khoa thi Tiến sĩ triều Mạc trong cuốn "Các nhà khoa bảng Việt Nam" (Recalculating some reign years of the National Examinations during the Mac (莫) Dynasty). In *Confucian Scholars in Vietnam*. Hanoi, Literature Publishing House. Pp. 39–44 (in Vietnamese).
Lân, T.L., 2000. *Lịch và niên biểu lịch sử hai mươi thế kỷ (0001–2010)* (*The Cumulative Calendar and Historical Chronology of Twenty Centuries* (*0001–2010*)). Hanoi, Thong ke Publishing House (in Vietnamese).
Lân, T.L., 2002. Một vài ghi chú về niên đại nhà Mạc cho bộ "Khâm định Việt sử thông giám cương mục" (Some notes on dates in the Mac (莫) Dynasty for 欽定越史通鑑綱目). In *Proceedings of The Scientific Workshop: Teaching and Researching History of the Nguyễn Tense for University, Pedagogical College and Popular School. October, 23–24, 2002.* Hanoi, Pedagogy University Hanoi. Pp. 289–297 (in Vietnamese).
Lân, T.L., and Dũng, T.N., 2003. Giáo sư Hoàng Xuân Hãn nói về lịch Tây Sơn (What Professor Hoang Xuan Han said about the calendar of the Tây Sơn Dynasty). I*n Archeological New Finds in 2002*. Hanoi, Social Science Publishing House. Pp. 780–782 (in Vietnamese).
Lân, T.L., 2005. Lập công thức để hiệu đính các cuốn lịch cổ (Establishing the formulae for revision of the ancient calendars). In *Bulletin of Han-Nom Studies 2004*. Hanoi, Institute of Han-Nom Studies. Pp. 303–313 (in Vietnamese).
Lân, T.L., 2006a. Vận dụng toán học để hiệu đính cuốn lịch cổ Bách trúng kinh (An application of mathematics for the revision of the ancient calendar of 百中經). In *Some Current Issues in Information Technology and Applied Mathematics*. Hanoi Institute of Techniques Military. The 14th Scientific Workshop Proceedings. ITMath'06. Pp. 65–72 (in Vietnamese).
Lân, T.L., 2006b. Vận dụng toán học để hiệu đính cuốn lịch cổ Khâm định vạn niên thư (Application of mathematics for the revision of the ancient calendar of 欽定萬年書). In *The 20th Scientific Workshop Proceedings*. Hanoi, Technical University Publishing House. Pp. 273–278 (in Vietnamese).
Lân, T.L., 2006c. Quê hương và ngày giỗ của Lý Nam Đế (The native place of King Ly Nam De and the date of his death). In *Added Discussion to Fully Understand and Rectification to give Exactly*. Hanoi, People's Army Publishing House. Pp. 16–34 (in Vietnamese).
Lân, T.L., 2006d. Bàn về ngày mất của vua tôi Quang Trung (The date of King Quang Trung and his underlings' death). In *Added Discussion to Fully Understand and Rectification to give Exactly.* Hanoi, People's Army Publishing House. Pp. 100–110 (in Vietnamese).
Lân, T.L., 2007a. Vận dụng toán học để hiệu đính cuốn lịch cổ Lịch đại niên kỷ Bách trúng kinh (An application of mathematics for the revision of the

ancient calendar 歷代年紀百中經). *In Proceedings of Scientific Workshop of the Institute of Information Technology on the Occasion of the 30th of His Foundation, December, 27–28, 2006*. Hanoi Sciences and Technologies Publishing House. Pp. 523–530 (in Vietnamese).

Lân, T.L., 2007b. *Đối chiếu lịch Dương với lịch Âm-Dương của Việt Nam và Trung Quốc 2030 năm (0001–2030) – Solar Calendar Comparison with Vietnamese and Chinese Lunisolar Calendar 2030 Years (0001–2030)* – 越南和中國 2030 年 (0001–2030) 陽曆與農曆對照. Hanoi, Education Publishing House (in Vietnamese, English and Chinese).

Lân, T.L., 2009. Về văn bản cuốn "Lịch đại niên kỷ Bách trúng kinh" (On the text of 歷代年紀百中經). In *Bulletin of Han-Nom Studies 2009*. Hanoi, Han Nom Research Institute. Pp. 606–618 (in Vietnamese).

Lân, T.L., 2010. *Năm trăm năm lịch Việt Nam* (*1544–2043*) (*Calendar for Five Hundred Years of Vietnam* (*1544–2043*)). Hanoi, Hanoi Publishing House (in Vietnamese).

Lân, T.L., and Dũng, T.N., 2011. Hai cha con họ Đặng và Lịch học Việt Nam xưa (Father and son of the Dang Family and the ancient Vietnamese calendar). *The Magazine for Research and Development*, 5(88), 111–117 (in Vietnamese).

Lân, T.L., 2013. Đôi lời chiều tuyết cho Đặng Nhữ Lâm (Nhân đọc cuốn Tìm hiểu trận tuyến bí mật trong lịch sử Viết Nam). (Some words explain for Dang Nhu Lam (By reading *Learn Secrets Fronts in the History of Vietnam*). *Journal of Historical Research*, 491(1), 65–72 (in Vietnamese).

Lân, T.L., 2014. Giáo sư Hoàng Xuân Hãn, người đặt nền móng cho nền lịch pháp Việt Nam (Professor Hoang Xuan Han – the founder of Vietnamese calendar methodology). *Journal of Historical Research*, 10(462), 22–31, 74 (in Vietnamese).

Lân, T.L., 2016. *Sổ tay niên biểu lịch sử Việt Nam* (*Manual on Vietnam Historical Chronology*). Hanoi, Politics National-Truth Publishing House (in Vietnamese).

Lân, T.L., and Nguyễn, T.T., 2017. Researching ancient Vietnamease calendars. In Nha, I.-S., Orchiston, W., and Stephenson, F.R. (eds.), *The History of World Calendars and Calendar-making. Proceedings of the International Conference in Commemoration of the 600th Anniversary of the Birth of Kim Dam*. Seoul, Yonsei University Press. Pp. 31–46.

Lê Qúy Đôn (黎貴敦), 1978. *Đại Việt thông sử* (大越通史-*General History of Đại Việt*). Hanoi, Social Sciences Publishing House (in Vietnamese).

*Lịch đại niên kỷ bánh trúng kinh* (曆代年紀百中經]. Coded A 1237 by the Library of the Institute for Han-Nom Studies (n.d., b) (in Vietnamese).

Ngô Sĩ Liên và các sử quan nhà Lê (吳士連 and National Historical Office of Lê Dynasty), 1993. *Đại Việt sử ký toàn thư* (大越史記全書 – *Complete Annals of Đại Việt*). Hanoi, Social Sciences Publishing House (in Vietnamese).

Nhí, T.N., 1995. *Phượng Dực đăng khoa lục* (鳳翼登稞錄). Hanoi, Social Sciences Publishing House (in Vietnamese).

Okazaki, A., 2017. Astronomical records in Vietnamese historical sources and the Vietnamese luni-solar calendar. In Nha, I.-S., Orchiston, W., Stephenson, F.R., and Kim, J. (Eds.). *The History of World Calendars and Calendar-making. Proceedings of the International Conference in Commemoration of the 600th Anniversary of the Birth of Kim Dam (1416–1464).* Seoul, Yonsei University Press. Pp. 47–52.

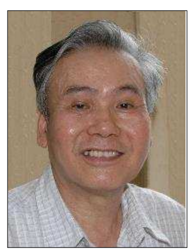
Phan Thúc Trực (潘叔直), 2009. *Quốc sử di biên* (國史遺編). Hanoi, Publisher of Culture and Information (in Vietnamese).

Quốc sử quán Thế kỷ XIX (The Nineteenth Century National Historical Office), 1957–1960. *Khâm định Việt sử thông giám cương mục* (欽定越史通鑑綱目 – *The Imperial Ordered Annotated Text Completely Reflecting the History of Việt*). Hanoi, Literature History and Geography Publishing House (in Vietnamese).

Quốc sử quán Thế kỷ 19 (The Nineteenth Century National Historical Office). 1963. *Đại Nam thực lục* (大南寔錄錄 – *Chronicle of Đại* Nam). Hanoi, Literature History and Geography Publishing House (in Vietnamese).

Thọ, N.Đ. (ed.), 1993. *Các nhà khoa bảng Việt Nam* (*Confucian Scholars in Vietnam*). Hanoi, Literature Publishing House (in Vietnamese).

Vietnamese Meteorological Service, 1967. *Lịch thế kỷ XX. 1901–2000* (*The calendar for the XXth Century*). Hanoi, General Publishing House (in Vietnamese).



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# THE CALENDARS OF SOUTHEAST ASIA. 4: MALAYSIA AND INDONESIA

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**Abstract:** The archipelago region of Southeast Asia is characterised by a great number of calendars of which we treat only a few. The early calendars were essentially original Indian calendars although with modified intercalation schemes. From the fifteenth century in the Christian era the region was increasingly dominated by Islamic influences and successively adopted Muslim calendars although with some modifications.

**Keywords:** History of astronomy, calendars, Malaysia, Indonesia, *mangsa* calendar

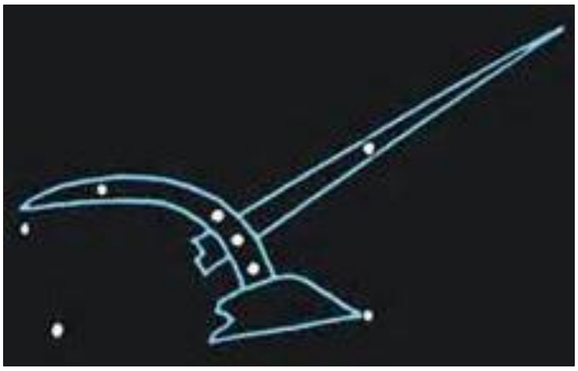
## 1 THE AGRICULTURAL CALENDARS

In Indonesia[1] there is an ancient harvest calendar[2] that is quite widespread and still extant that uses the constellation of Orion (Dhitasari, n.d.). For locations on the Earth close to the equator, the rising and setting of this constell-ation (plus three of the four outer stars and excluding Betelgeuse) appears to be lying on its side and is in Indonesia seen to resemble a traditional Javanese plough (*waluku*)—see Figure 1. The heliacal rise of Orion, its first appearance at dawn above the eastern horizon, occurs close to the summer solstice. It then looks like an upright plough and marks the start of the harvest year. It then rises more and more early in the night. About five months later the constellation has its acronycal rise, the last time it rises after sunset, when Orion and the Sun are almost opposite each other, which indicates that it is time for rice planting. Four months later Orion has passed its culmination at sunset and is then to be seen setting in the evening Western sky but now upside down. The planting season is then over, and it is time to put away the plough.

Many people in the Indonesian archipelago use stars or group of stars like the Pleiades to determine agricultural activities (Ammarell, 1988). The most common method is to use heliacal phenomena, i.e. the position of the marker stars at sunset or sunrise. Raising and settings may be difficult to see due to forest vegetation and often the heliacal culminations are used instead. Sometimes the altitude of a specific star at some specified time was used to mark important events like planting of rice.

One way of measuring the altitude of a selected star at a selected moment is the bamboo device (Figure 2) documented by Hose and McDouhall (1912) from Borneo. The bamboo cylinder is filled to the rim with water and then pointed at the star. When held vertical again, the water level indicates the altitude of the star which in turn tells if it is time to plant rice.

In Java there is also, still in use, an ancient solar calendar used for agriculture, the *mangsa* (seasons) calendar. It has 12 solar months with different lengths (Dhitasari, n.d.; Ginzel, 1911: 128, Van den Bosch, 1980; Van Sandick, 1885). The original way of setting up the calendar was to use a vertical stick, a gnomon (Figure 3) on which the positions of the noon shadow were marked at the summer and winter solstices. As Java lies south of and close to the equator, the



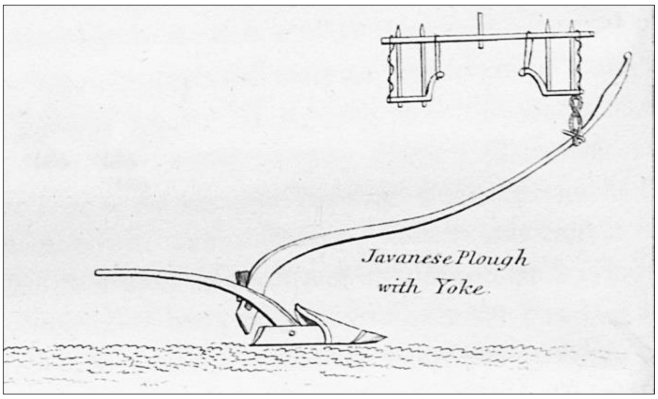



Figure 1a (left): Orion as a plough (after Dhitasari, n.d. ). Figure 1b (right): Javanese plough (after Crawfurd, 1820: Plate 14).

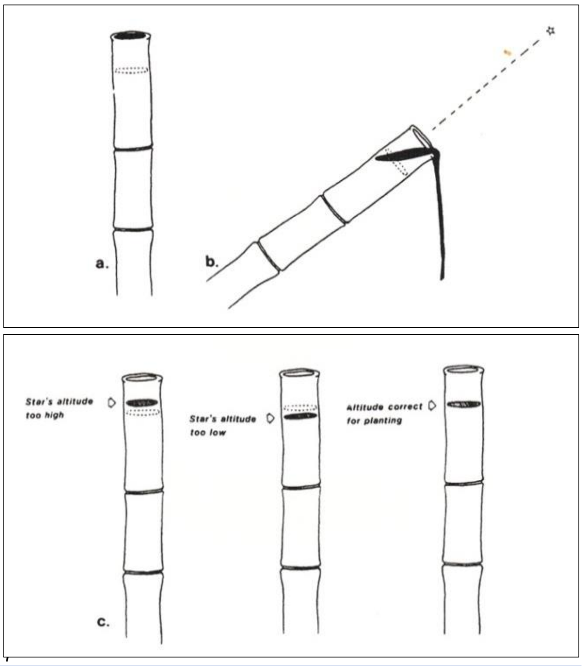


Figure 2: A bamboo device for measuring the altitude of stars (based on Hose and McDougall, 1912: 109).

noon Sun will be north of the zenith on the summer solstice and south of the zenith on the winter solstice and these two extremal positions will be situated on either side of the foot of the gnomon. The interval between these positions is divided into six equal parts, each part representing a solar month. As the Sun spends a longer time close to the solstices and shorter time near the equinoxes, the extremal months will be longer and the middle months shorter. As the Sun moves from equinox to equinox it will spell out a solar year with twelve unequal months.

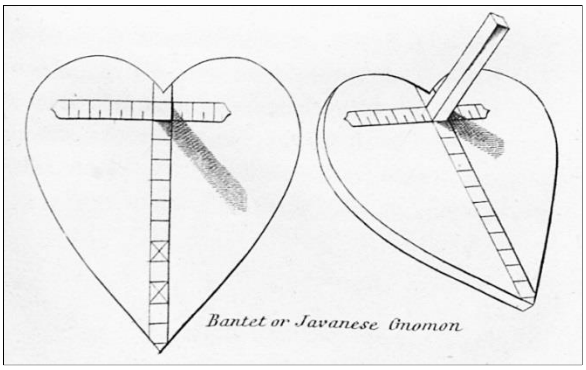


Figure 3: A Javanese gnomon (after Crawfurd, 1820: Plate 14).

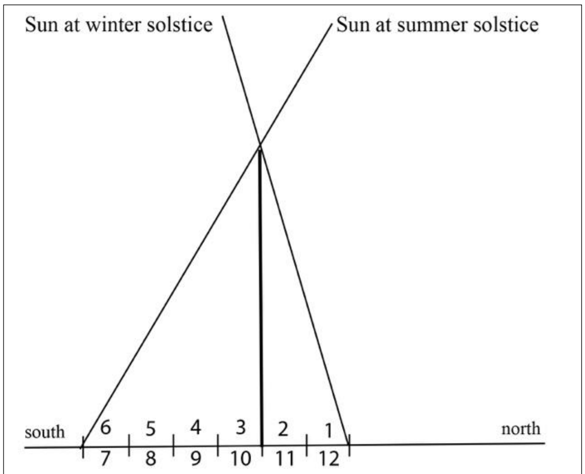


Figure 4: Measuring solar shadows (diagram: Lars Gislén).

Central Java is situated at a geographical latitude of about 7.5° S. At the summer solstice the noon Sun will have a zenith angle of about 31° north, at the winter solstice the noon zenith angle will be 16° south (see Figure 3). With a gnomon height of *G*, the summer equinox noon shadow will have a length of $G \times \tan 31° = G \times 0.60$, the winter solstice noon shadow will have a length of $G \times \tan 16° = G \times 0.29$. The summer shadow will very nearly be twice the length of the winter shadow and we can divide the distance between these extremes shadows into six parts, each having a length of $G \times 0.15$, two of the divisions being north of the foot of the gnomon and four of them being south of the gnomon (see Figure 4).

Table 1: Javanese months.

| |
|---|
| Kasa |
| Karo |
| Katiga |
| Kapat |
| Kalima |
| Kanem |
| Kapitu |
| Kaulu |
| Kasanga |
| Kadasa |
| Destha/Jiestha |
| Sadha |

Sultan Pakubuwono VII (1796–1858) of Surakata standardised the length of these months to 41, 23, 24, 25, 27, 43, 43, 26, 25, 24, 23, and 41 days, starting from the summer solstice. Every fourth solar year is a leap year when the month with 26 days instead gets 27 days. The epoch of this standardised calendar is the summer solstice on 22 June 1855. These 12 months are sometimes grouped three by three in *mangsa utama* (main seasons) of 41 + 23 + 24 = 88, 25 + 27 + 43 = 95, 43 + 26/27 +24 = 94/95, and 24 + 3 + 41 = 88 days. The names of the Javanese months are given in Table 1. This table shows the names of the solar months. The first ten names are merely Javanese ordinal number, the last two names are of unknown origin. Figure 5 shows a bowl with the signs of the solar months (upper row) and the corresponding Indian months (bottom row, right to left).

There are several other calendrical methods based on the altitude of the Sun in the Indonesia-Malaysia region (Ammarell, 1988; Maass, 1924). The Kenyah people in northern Borneo use a straight cylindrical pole (*tukar*) with a length equal to the span of the maker's outstretched arms plus the span from the tip of the

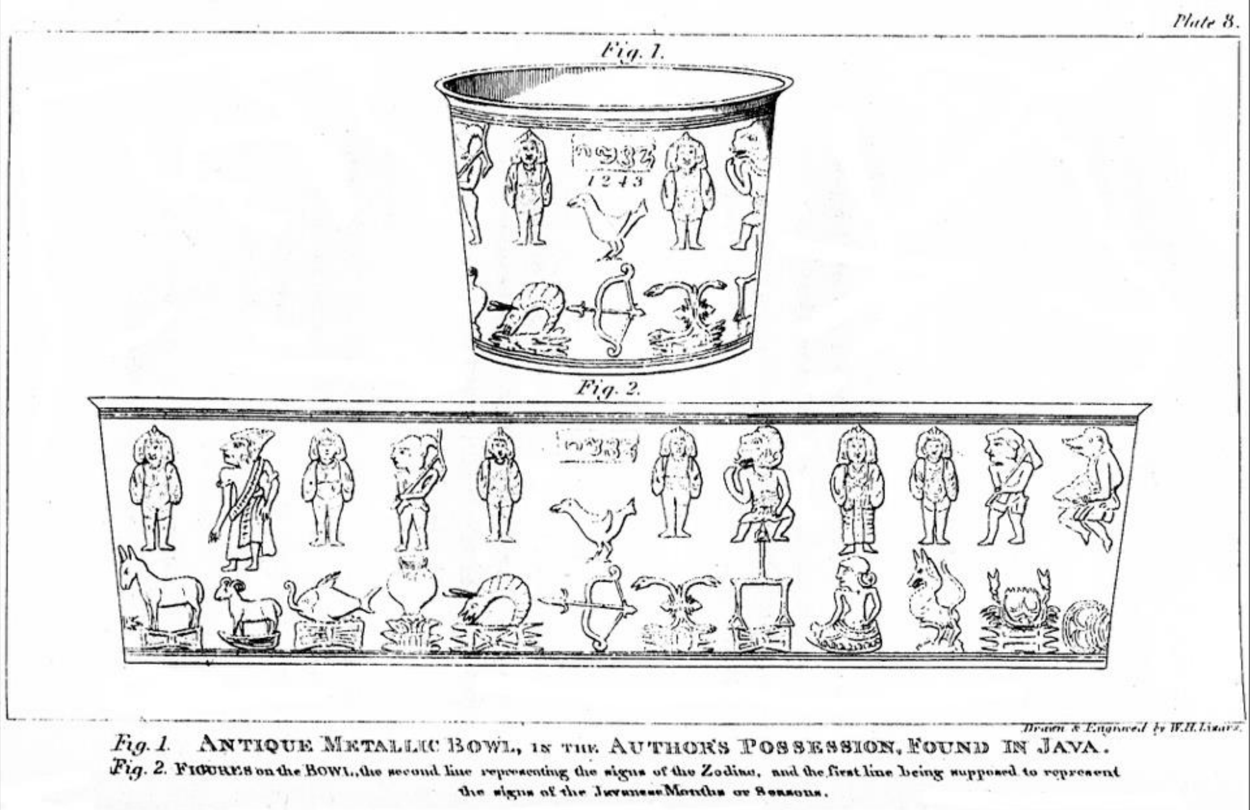



Figure 5: Signs of Javanese and Indian months (after Crawfurd, 1820: Plate 8).

thumb to the first finger (Figure 6). This system uses the noon shadow of the pole. It is carefully set vertical using plumb lines and fixed in its lower end to a horizontal board. The shadow length is measured with a stick, also fitted to the size of the maker (Figure 7) with a length equal to the distance from the maker's armpit to the tip of the fingers. The stick is marked with notches corresponding to important dates for agriculture.

## 2 THE BATAK CALENDAR

The Batak people in northern Sumatra have a traditional luni-solar calendar called Porhalaan that was still in use in the beginning of the twentieth century and where the start of the year is determined as follows (Maass, 1924: 23–25). The year begins when the constellation of Orion sets in the Western sky in the evening while at the same time the constellation Scorpio with the bright star Antares (α Scorpii) rises in the east. The first day of the first month then occurs with the appearance of the new Moon crescent rising in the east north of Orion under these conditions. This normally happens in May. Fourteen days later, the rising full Moon in the east having moved about 180° in the starry sky, will pass the constellation of Scorpio, an important calendrical event in the calendar. The following months start by the first appearance in the evening of the New Moon crescent. The Moon will pass Scorpio about two days earlier each month as the difference between the synodic and sidereal months is 29.53 – 27.32 = 2.21 days. Figure 8

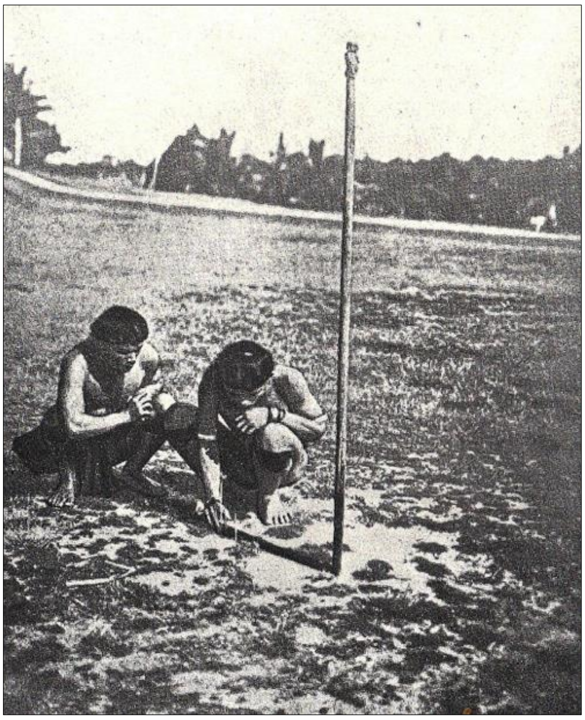


Figure 6: A solar gnomon (after Maass, 1924: Figure 24).

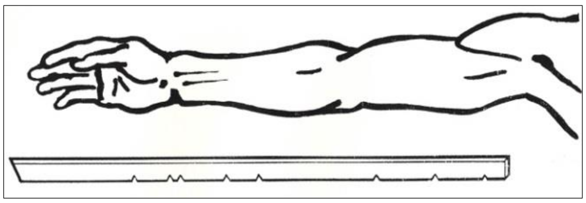


Figure 7: The base of the solar gnomon (after Ammarell, 1988: 87).

Figure 8: Batak calendar (Museum of Anthropology, University of Michigan, Bartlett Collection).

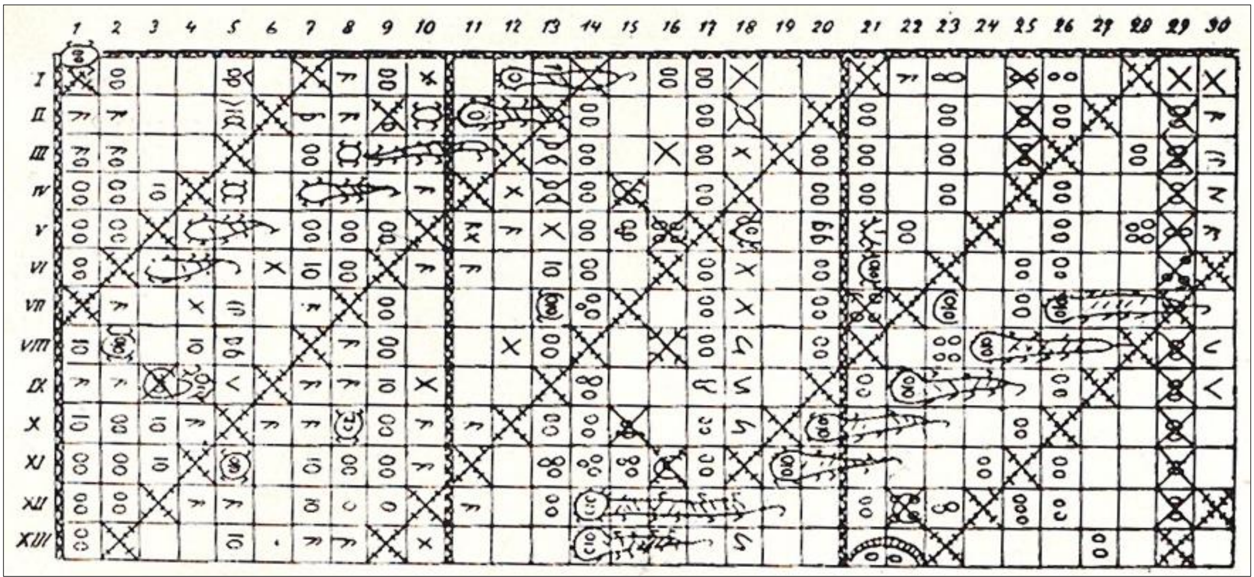


Figure 9: Batak calendar layout (after Maass, 1924: Figure 1).

shows a Batak calendar engraved on a bamboo cylinder. The calendar is made as a matrix with 12 rows of months, sometimes 13, each month having 30 lunar days. The layout of calendar matrix is shown in Figure 9 where day number 15 is the full Moon day. Some days are marked with the picture of a scorpion (looking like a worm), see for example the days in to the left in rows V and VI in Figure 9. The calendar is used for divination, the days in the matrix being marked with different symbols forming a kind of daily horoscope and where the days covered by scorpions have a special propitious significance.

Table 2: Names of the Pawukon weeks.

| Day of the week | Name |
|---|---|
| 1 | Ekawara |
| 2 | Dwiwara |
| 3 | Triwara |
| 4 | Caturwara |
| 5 | Pancawara |
| 6 | Sadwara |
| 7 | Saptawara |
| 8 | Astawara |
| 9 | Sangawara |
| 10 | Dasawara |

## 3 THE PAWUKON CALENDAR

The Pawukon calendar is specific to Bali (Reingold and Dershowitz, 2018) and was brought to Bali with fleeing Hindu Majapahitis in the fourteenth century (Eiseman, 1990: 223). It is a 210-day cyclical calendar, which in some respects is similar to the 5-, 6-, and 7-day *wuku* calendar in Java but is considerably more elaborate. It consists of 10 kinds of parallel weeks containing respectively 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 days (Table 2). The most important are the 3-, 5-, and 7-day weeks. The weeks with three, five, six, and seven days are merely a cyclical sequence of the days of the week, as for the Javanese *wuku* calendar. Table 3 shows the names of the individual days in the different weeks.

As 210 is not divisible by 4, 8, and 9, certain weekdays have to be repeated in order to fit into the scheme. For the 4- and 8-day weeks the penultimate weekday is repeated twice in a week

Table 3: Names of the days in the weeks.

| Week / Day | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Ekawara | Luang | | | | | | | | | |
| Dwiwara | Menga | Pepet | | | | | | | | |
| Triwara | Pasah | Beteng | Kajeng | | | | | | | |
| Caturwara | Sri | Laba | Jaya | Menala | | | | | | |
| Pancawara | Paing | Pon | Wage | Keliwon | Umanis | | | | | |
| Sadwara | Tungleh | Aryang | Urukung | Paniron | Was | Maulu | | | | |
| Saptawara | Redite | Coma | Anggara | Buda | Wraspati | Sukra | Saniscara | | | |
| Astawara | Sri | Indra | Guru | Yama | Ludra | Brahma | Kala | Uma | | |
| Sangawara | Dangu | Jangur | Gigis | Nohan | Ogan | Erangan | Urungan | Tulus | Dadi | |
| Dasawara | Pandita | Pati | Suka | Duka | Sri | Manuh | Manusa | Raja | Dewa | Raksasa |

that would otherwise have ended on the 72nd day; and the first 9-day week in the 210-day cycle begins with four occurrences of the first day. The weeks with one, two, and 10 days have a more complicated intercalation, and the procedure for determining the sequence of week-days for these weeks is as follows: each week day of the 5- and the 7-day weeks is associated with a unique number, the *urip*. Table 4 shows these.

For a given day in the 210-day cycle, you find the *urip* of its weekday in the 5-day and 7-day weeks. You add the *urip* numbers and increase the sum by 1. If the total is greater than 10 you subtract 10. If the resulting number is even, the 1-day weekday is Luang and the 2-day weekday is Pepet; if it is odd the 1-day weekday is without name and the 2-day week-day is Menga. The day in the 10-day week is the one with the calculated number.

Example: On the 57th day of the 210-day cycle, the 5-day week is Pon, number 2 and the 7-day week is Redite, number 1. The respective *urip* numbers are 7 and 5. 7 + 5 + 1 = 13. 13 – 10 = 3, an odd number. Thus the 1-day weekday is without a name, the 2-day weekday is Menga, and the 10-day weekday is Suka.

There are 30 wuku weeks of the 7-day week in a 210-day year. Each of these has a name (see Table 5). The names are almost all the same as or similar to the corresponding week names in the Javanese wuku calendar that uses a subset of the Pawukon weeks: the 5-day, the 6-day, and the 7-day weeks.

The Pawukon calendar cycles are unnumbered and can be extended arbitrarily in time. Thus, for example 3 February 2019 was Luang-Pepet-Beteng-Jaya-Wage-Was-Redite-Kala-Jangur-Raksasa, cyclical day 113 in the seven-day week Krulut.

Certain combinations of the cycles generate days of celebration like the 3- and 5-day combination Kajeng-Keliwon. The combination of the last day of the 7-day week, Saniscara and the day Keliwon in the 5-day cycle is called a *tumpek*. Day 74 in the Pawukon cycle, the Galungan Day, day 84, the Kuningan Day, is both a *tumpek* and Kajeng-Keliwon. In the period between these two days the most important celebrations are held.

Table 4: *Urip* numbers.

| Day / Week | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Pancawara | 9 | 7 | 4 | 8 | 5 | | |
| Saptawara | 5 | 4 | 3 | 7 | 8 | 6 | 9 |

A *tika* calendar is used in order to keep track of the most important of the weeks and days in the Pawukon calendar. The *tika* is a pattern of squares laid out in seven rows, representing the seven weekdays, and 30 columns representing the 30 7-day weeks in the Pawukon cycle. *Tikas* are either carved on wood or painted on cloth. Geometrical figures—dots, crosses, and circles—symbolize the various auspicious days and week cycles. Figure 10 shows an example of a *tika* carved in wood.

## 4 THE INDIAN CALENDAR

This section draws heavily on the excellent paper of Ian Proudfoot (2007).

The generic Indian calendar has a long history in Java and Bali. Dates in an Indian calendar appear in Java's oldest historical documents from the dated inscriptions of the eighth century. They continue right through the record of inscriptions in Java and Bali up to the fall of Majapahit Empire in the fifteenth century of the Common Era. Subsequent dates in Indian calendars appear in Old Javanese and Balinese liter-

Table 5: The 7-day week names

| Week number | Name | Week number | Name |
|---|---|---|---|
| 1 | Sinta | 16 | Pahang |
| 2 | Landep | 17 | Krulut |
| 3 | Ukir | 18 | Merakih |
| 4 | Kulantir | 19 | Tambir |
| 5 | Taulu | 20 | Medangkungan |
| 6 | Gumbreg | 21 | Matal |
| 7 | Wariga | 22 | Uye |
| 8 | Warigadian | 23 | Menail |
| 9 | Julungwangi | 24 | Parangbakat |
| 10 | Sungsang | 25 | Bala |
| 11 | Dunggulan | 26 | Ugu |
| 12 | Kuningan | 27 | Wayang |
| 13 | Langkir | 28 | Kelawu |
| 14 | Medangsia | 29 | Dukut |
| 15 | Pujut | 30 | Watugunung |

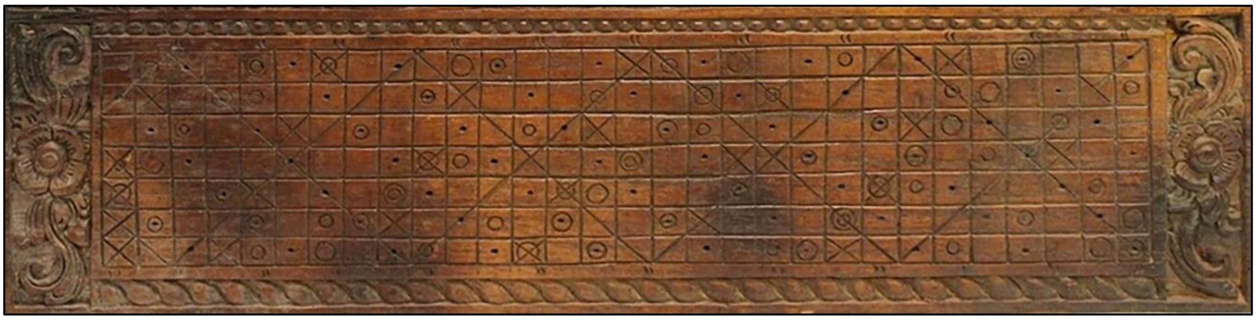


Figure 10: Part of a wooden *tika* calendar (Lars Gislén Collection).

ary sources and in administrative instruments issued by the courts of Bali and Lombok into the twentieth century. Indian calendars are still used in Bali for religious purposes.

The original Indian calendar was reformulated using locally adapted rules but retaining fundamental parts of the original calendar like the beginning the month with the new Moon, beginning the year near the Spring equinox, and enumerating the years in the Śaka Era (CE 78) as elapsed years. However, the finer point of Indian astronomy seems to have been lost in the transition from India. Therefore, it cannot be expected that the Javanese records would precisely conform to the astronomy of the *Sūryasiddhānta.* In fact, there is clear evidence to the contrary. The intercalation system of *Sūryasiddhānta* with its insertion of lunar months into its calendar confines itself for most of the time to the months from Vaisakha to Karttika whereas the Javanese intercalation system extends itself across the entire year. The Balinese astronomers in particular wanted to relate the Śaka calendar with their day-cycles used for Javanese and Balinese divination. Very early in the inscriptions the Śaka dates are accompanied by information about the three key day-cycles: the 6-day, the 5-day, and the 7-day cycle that combine in an endlessly repeating 210-day cycle, the wuku.

In the Śaka scheme there is a suppression of the tithi number when there is a *tithi* that is not current at any day, that is to say the *tithi* begins after sunrise on one day and is complete before sunrise on the next day. This can happen because the *tithi* is slightly shorter than a civil, solar day. Twelve lunar months, each containing 30 *tithi* make up a lunar year of 360 *tithi*. However, the lunar year corresponds to 12 lunations, each with on average 29.53059 days giving a total of 354.367 civil days. Thus, there will on average be 360 – 354.367 = 5.633 *tithi* that are suppressed. There will on average be one *tithi* suppressed every 354.367/5.633 = 62.9 solar days. Now it happens that this number is almost exactly 63 days, and 63 days exactly equals nine seven-day weeks. This consideration allows the pattern of suppressions to engage with the wuku cycle. This kind of calendar is implemented in the Balinese Śaka calendar, see Section 5 below. It is possible to list the successive named weeks in which suppression occurs, to form a cycle that repeats after 10 suppressions, or ninety weeks or 630 days. This is called *pangalantaka*. This cycle contains three 210-day cycles, another bonus.

In this scheme the Śaka calendar meshes nicely with the wuku cycles. What about the suppressed *tithi*? After each *pangalantaka* there will be 10 suppressed *tithi*, so that after three *pangalantaka* there will be 30 of them, just enough to make an intercalary lunar month in the Śaka calendar. A seemingly perfect assimilation has been made with the two calendars. An intercalary month occurs after each 3 × 630 = 1890 day. As 1890 days amounts to five years plus three months, the month that will be repeated is predictable according to a cycle of its own. The first intercalated month will be the 11th, the next, five years and three months later will be the second, then the fifth and then the eighth. After that the cycle repeats. The whole pattern or metacycle lasts 4 × 1890 = 7560 days and contains all the day cycles, of 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 days, the cycle of 35 days, 210 days and so on—a spectacular result.

However, this is just a theoretical speculation built on a confusion between *tithi* and calendar days. A suppressed *tithi* merely means that a civil day contains two *tithi* and at the end of the month the *tithi* on that day will be 29 civil days giving the impression that at *tithi* has been lost. It is quite common not only in Javanese inscriptions that there is a confusion between lunar days, *tithi* and civil day reckoning, something which shows that the connection of the calendar with the original Indian astronomy had become lost. Intercalation of a lunar month about every five years would rapidly make the lunar calendar lose connection with the seasons, what is needed is an intercalation about every 33 months. Instead, it seems that in practice in many regions like in Bali, the intercalation was make when needed by observation of the seasons. For this purpose, the constellations of Orion and the Pleiades were used, the first month of the star-based year began with the heliacal rising of Orion.

The problem of how the intercalation was made in practice has been investigated (Eade and Gislén, 2000; Proudfoot, 2007) with some different conclusions. The necessary intercalation would approximately need an extra month every 33 months or three years minus three months. If the first intercalated month would be the eleventh, the next one would be the eighth, then the fifth then the second, then the series would repeat. This would be the mirror image of the cycle above. Proudfoot (2007) found by testing that for Śaka years after 1040 this intercalation scheme actually works very well.

## 5 THE BALINESE ŚAKA CALENDAR

Bali has an ancient calendar that is slightly different from the traditional Indian Śaka calendar in Java. The Bali scheme (Eiseman, 1990: 220) has a lunar year with 12 months, each with 30 *tithis*. There are 15 *tithis* of waxing Moon, the *penanggal*, and 15 days of waning, the *pangelong*. Each lunar month starts on the day after new Moon, *tilem*. When converting the *tithis* to solar days, on every 63rd solar day or on every ninth week two *tithis* fall on the same solar day and a *tithi* is supressed. Such a day is called *ngunaratri* from Sanskrit meaning 'minus one night'. Taking it that 11 January 1950 has a suppressed *tithi* all other days with a suppressed *tithi* can be calculated. The fact that the distance between suppressed *tithis* is exactly nine weeks means that the calendar weekday is the same for all days with suppressed *tithis*. Before CE 2000 it was Wednesday.

A *tithi* corresponds to 63/64 solar days, thus generating a synodic lunar month of 30 × 63/64 = 29.53125 days. This is slightly longer than the true synodic month, 29.53059 days, which means that the suppression scheme has to be corrected by one day approximately every 122 years. This was for example done in CE 2000 when there was a step by only 62 days from the last suppressed *tithi* in the previous year, Wednesday 17 November to the first suppressed *tithi* on CE Tuesday 18 January 2000.

In order to align the lunar calendar with the solar year it is necessary to intercalate an extra lunar month about every 33 months. Before the middle of the twentieth century this intercalation was done 'when needed' and there was no definite intercalation rule. From about CE 1950 to 1992 the intercalation was determined by cyclical years in a 19-year cycle (Śaka year modulus 19) where 0, 3, 6, 8, 11, 14, and 16 are the cyclical years with an intercalated month and with month 11 being doubled for cyclical years 0, 6, and 11, and month 12 being doubled for the other cyclical years. In the interval CE 1992–2000 the cyclical years with an intercalary month were 2, 4, 7, 10, 13, 15, and 18 with corresponding doubled months according to Table 6, although only cyclical years 2 and 18 were implemented. From CE 1 January 2000 the intercalation reverted to the earlier system. To restore the calendar at the year shift CE 2000/2001, 6 Kaulu (the eighth month) was followed by 7 Kapitu (the seventh month), effectively intercalating a month.

The Bali New Year Day, the *nyepi*, is supposed to be a day of silence, prayer, and meditation and falls on the first day of the tenth month, Kadasa. This day normally falls in March around the time of the vernal equinox.

Figure 11a shows a month in a typical Balinese calendar taken from the website http://www.kalenderbali.info/?month=3&year=2019&submit=Tampilkan. At the top is the Śaka year 1940 which begins in the Gregorian calendar on 7 March 2019. The large numbers show the dates in this calendar. New and Full Moons are shown as a black or a red circle respectively. The *tithis* are represented by a small number in the upper left corner, red for waxing Moon and black for waning Moon. The date 12 March has a suppressed *tithi* as shown by two *tithi* numbers 6/7. Figure 11b shows a detail of 7 March, the *nyepi* or New Year Day, the first day of month 10, Kadasa. It also displays the Pawukon weekdays, in this case, the 1-day weekday is Luang, the 2-day weekday is Pepet, the 3-day weekday is Pasah, the 4-day weekday Jaya, the 5-day weekday Umanis, the 6-day weekday Tungleh, the 8-day weekday Kala, the 9-day weekday Urukung, and the 10-day weekday Duka. The 7-day weekday Wraspati appears above 7-day week name, Matal. The bottom line, *ingkel*, shows a sequence of six names of the 7-day weeks in a repeating cycle of 42 days and has astrological significance.

Table 6: Intercalary months.

| Cyclical Year | Doubled month |
|---|---|
| 2, 10 | 11 |
| 4 | 3 |
| 7 | 1 |
| 13 | 10 |
| 15 | 2 |
| 18 | 12 |

## 6 THE ISLAMIC CALENDAR

Muslim traders visited the Southeast Asian archipelago already in the sixth and seventh centuries profiting from the flourishing trade between India and China. During the following centuries Islam gradually spread and was, around CE 1500 when the Majapahit Empire had collapsed, the dominant religion, but with Bali as an exception. Most of the local rulers were then Muslims. The original Muslim calendar is purely lunar, with each year

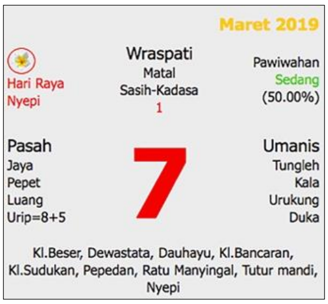




Figure 11a (right): The Balinese Calendar.
Figure 11b (above): Calendar details.

having 12 lunar months, each lunar month starting with the first observation in the evening of the new Moon crescent.

However, the rapid geographic expansion of the Muslim Empire made it pressing to have a standard civil calendar, which was introduced by the Caliph Umar in the eighth year after the death of the Prophet. The calendar had 12 months with alternating 30 and 29 days, and a total of 354 days in a year. To keep in step with the Moon a leap day was added to the last month of 11 intercalary days in a 30-year cycle. This will give 354 × 30 + 11 = 10631 days in a cycle and a synodical month of 10631/ (30 × 12) = 29.53056 days. The difference with the correct synodic month is only one day in about 2400 years.

In the Southeast Asian maritime area and on the Malay Peninsula the Muslim calendar appeared in a simplified variant based on an 8-year cycle (*windu*) (Proudfoot, 2006). As in the original Muslim calendar, the year (*tahun*) has 12 lunar months (*wulan*) with alternating 29 and 30 days. In this 'octaval' calendar, three leap years were distributed through each eight years with years 2, 5, and 7, or sometimes the years 3, 5, and 8 being leap years. This calendar will not be quite as accurate as the original Muslim calendar, having a slightly longer synodic month: (354 × 8 + 3)/(8 × 12) = 29.53125 days. However, an 8-year cycle contains 5 × 354 + 3 × 355 = 2835 days that happens to comprise exactly 407 7-day weeks and also exactly 567 5-day weeks. The result is that if one cycle begins on a particular weekday, so will the next and the beginning weekday of each year within the 8-year cycle will be determined and constitute the signature of that year. In order to align the calendar with the Moon the calendar in the can-

Figure 12: Sultan Agung on an Indonesian stamp.

onical version was adjusted by skipping the last leap day in the last 8-year cycle every 120 years (*kurup*) or 15 windu blocks. Thus, in a 120-year block there are 15 × 2835 – 1 = 42524 days with a total of 3 × 15 – 1 = 44 = 4 × 11 intercalary days. There will be exactly the same number of intercalary days in the Muslim arithmetic calendar, which has a leap year cycle with its 11 leap years in 30 years but the intercalation scheme will be slightly different. In practice it seems that the suppression of the leap day was more flexible and was made as the need was seen to arise and not at precisely regular intervals.

These 'octaval' variants of the Muslim calendar were gaining a foothold in Southeast Asia beginning with the Malacca Peninsula in about CE 1400 according to Malay sources (Proudfoot, 2006). There were many local variants in the adjustment of the calendar by skipping a leap day in order to align the calendar with the Moon.

In CE 1633 Sultan Agung (1613–1645; Figure 12), inaugurated this kind of calendar as the current calendrical system in Indonesia with the regular suppression of a leap day in 120 years. The calendar still retains the Śaka calendar era, CE 78. The calendar is completely different from the earlier luni-solar calendar that tried to synchronise with the Sun. This lunar calendar today runs alongside but separated from the Gregorian calendar.

On top of the 7-day week (Table 7) in the Gregorian and Muslim calendars there is a cyclic 5-day week (*pasaran*). Together they form a 7 × 5 = 35-day cycle (*wenton*) that is used for important celebrations and for divination.

Table 7: Indonesian weekdays.

| Indonesian weekdays | Indonesian weekdays |
|---|---|
| Sunday | Sunday |
| Monday | Monday |
| Tuesday | Tuesday |
| Wednesday | Wednesday |
| Thursday | Thursday |
| Friday | Friday |
| Saturday | Saturday |

## 7 CONCLUDING REMARKS

Originally, Indonesia has had a multitude of different calendars, which is not surprising considering the many relatively isolated islands in the region. A typical feature was the use of cycles of different kinds, the Pawukon calendar being an extreme case. The later part of the calendrical history the Malaysian-Indonesian region is dominated by octaval variants of the Muslim calendar.

## 8 NOTES

1. This is the fourth paper in the series on the traditional calendars of Southeast Asia. The first paper (Gislén and Eade, 2019a) provided an introduction to the series. Paper 2 was about Burma (present-day Myanmar), Thailand, Laos and Cambodia (Gislén and Eade, 2019b); and Paper 3 about Vietnam (Lân, 2019).
2. For specialist terms used in this paper see the Glossary in Section 10.1.

## 9 REFERENCES

Ammarell, G., 1988. Sky calendars of the Indo-Malay Archipelago: regional diversity/local knowledge. *Indonesia*, 45, 84–104.

Crawfurd, J., 1820. *History of the Indian Archipelago. Volume I*. Edinburgh, Archibald Constable & Co.

Dhitasari, N.N.A.C., n.d. *Indonesian Archaeoastronomy Project.* (https://spaceodyssey.dmns.org/media/63006/indonesianarchaeoastronomyproject-niyomandhitasari.pdf).

Eade, J.C., and Gislén, L., 2000. *Early Javanese Inscriptions. A New Dating Method*. Leiden, Brill.

Eiseman, F.B. Jr, 1990. *Bali: Sekalia and Niskala. Volume I: Essays on Religion, Ritual and Art.* Tokyo, Tuttle.

Ginzel, F.K., 1911. *Handbuch der Mathematischen und Technischen Chronologie*. II. Band. Leipzig, J.C. Hinrichs'sche Buchhandlung (in German).

Gislén, L., and Eade, C., 2019a. The calendars of Southeast Asia. 1: Introduction. *Journal of Astronomical History and Heritage*, 22, 407–416.

Gislén, L., and Eade, C., 2019b. The calendars of Southeast Asia. 2: Burma, Thailand, Laos and Cambodia. *Journal of Astronomical History and Heritage*, 22, 417–430.

Hose, C., and McDoughall, W., 1912. *The Pagan Tribes of Borneo.* London, Macmillan.

Lân, T.L., 2019. The calendars of Southeast Asia. 3: Vietnam. *Journal of Astronomical History and Heritage*, 22, 431–447.

Maass, A., 1924. Sternkunde und sterndeuterei im Malaiische Archipel. *Tijdschrift voor Indische Taal-, Land- en Volkenkunde*, LXIV, 1–172 (in German).

Proudfoot, I., 2006. *Old Muslim Calendars of Southeast Asia*. Leiden, Brill.

Proudfoot, I., 2007. In search of lost time. Javanese and Balinese understanding of the Indian calendar. *Bijdragen tot de Taal-, Land- en Volkenkunde (BKI)*,

163(1), 86–122.
Reingold, E., and Dershowitz, N., 2018. *Calendrical Calculations*. Cambridge, Cambridge University Press.
Van den Bosch, F., 1980. Der Javanesische mangsakalender. *Bijdragen tot de Taal-, Land- en Volkenkunde*, 136(2/3), 248–282 (in German).
Van Sandick, R.A., 1885. L'astronomie chez les javanais. *L'Astre*, 4, 367–372 (in French).

## 10 APPENDICES

### 10.1 Glossary

*acronycal rising* The last day when the star (after a period when it was visible at night) rises in the evening after sunset and the Sun is already far enough below the eastern horizon to make it visible in the evening twilight. See *heliacal rising* and *setting.*

*Balinese Śaka calendar* A calendar related to the traditional Śaka calendar in Java but with some special features.

*gnomon* A vertical pole casting a shadow of the Sun. It can be used for determining the time of the day or the time of the year.

*heliacal rising* The first day when the star (after a period when it was invisible) rises in the morning before the Sun and the Sun is still far enough below the eastern horizon to make it briefly visible in the morning twilight. See *acronycal rising*.

*heliacal setting* The last day when the star or planet (after a period when it was visible) sets after sunset and the Sun is already far enough below the western horizon to make the star briefly visible in the evening twilight. See *acronycal rising*.

*kurup* An Indonesian cycle of 120 lunar years.

*Majapahiti Empire* A thalassocracy based on the island of Java that existed from CE 1293 to about CE 1500. During its height it stretched from Sumatra to New Guinea.

*mangsa* An Indonesian agricultural solar calendar. *Mangsa utama* are the three main seasons in the Javanese *mangsa* calender.

*nyepi* The Balinese New Year day, the first day of month 10, Kadasa.

*Orion* A constellation used by many regions in Southeast Asia for calendrical purposes.

*pangalantaka* An Indonesian cycle of 630 days consisting of three 210-day cycles or ninety 7-day weeks.

*pangelong* Balinese for the waning phase of the Moon.

*pasaran* A 5-day week used in Indonesia in combination with the 5-day week.

*Pawukon* A Balinese cyclic calendar based on a combination of periods with 1-, 2-, 3, …, and 10-day 'weeks' generating a repeating 210-day period.

*penanggal* Balinese for the waxing phase of the Moon.

*Pleiades* A group of several quite dim stars that play an important rôle in Indian and Southeast Asian astronomy.

*Porhalaan* The traditional calendar used by the Batak people of northern Sumatra.

*Śaka era* An Indian era with epoch of CE 17 March 78. See *Mahasakarat era*.

*sasih* The Balinese lunar month.

*solstice* The moment of the year when the Sun is most north or south of the equator. The summer solstice occurs around 21 June, the winter solstice around 21 December.

*suppressed tithi* The days of the month in the lunar calendar are numbered by the *tithi* that is current on sunrise that day. In some months there is a *tithi* which is not current on any sunrise of the month. This can happen because the lunar day is somewhat shorter than the civil, solar day. That *tithi* is then suppressed.

*tahun* The Indonesian year of twelve lunar months, *wulan*.

*tika* A device to keep track of the cycles and celebration days of the Balinese *Pawukon* cycle. Carved in wood or painted on cloth.

*tilem* The last day in a Balinese lunar month, also being the day of new Moon.

*tithi* Originally a time unit being a lunar day of 1/30th of a synodic month, in Southeast Asian astronomy being 692/703 of a solar day. It can also refer to the lunar day number in a month and also the relative position of the Moon relative to the Sun, the possible 360° divided into 30 *tithis*, each one covering 12°. This unit of time was used already by the Babylonians.

*tukar* A cylindrical vertical pole used by the Kenyah people of northern Borneo for calendrical purposes.

*tumpek* A combination in the *Pawukon* calendar of the last day of the 7-day week, Saniscara and the day Keliwon in the 7-day cycle.

*urip* A number used in the *Pawukon* calendar to determine the weekday name of the 1-day, 2-day, and 10-day weeks.

*waluku* The traditional Javanese plough connected with the constellation of Orion and used as a calendar indicator.

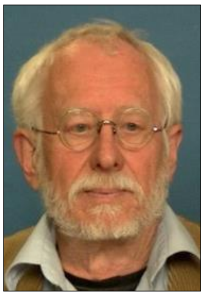
*wenton* An Indonesian 35-day cycle generated by the combination of a 5- and a 7-day cycle.

*windu* A block of eight Indonesian lunar years.

*wuku calendar* An Indonesian cyclic calendar

based on a combination of 5-, 6- and 7-day weeks.

*wulan* The Indonesian lunar month.



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# THE CALENDARS OF SOUTHEAST ASIA. 5: ECLIPSE CALCULATIONS, AND THE LONGITUDES OF THE SUN, MOON AND PLANETS IN BURMESE AND THAI ASTRONOMY

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**Abstract:** Many of the calendrical records in Southeast Asia contain information on the longitudes of the Sun, the Moon and the planets—something that is valuable for the dating of these records. Both the Burmese and the Thai use calculation schemes for the longitudes of the Sun, the Moon, and the planets that are almost identical to the original *Sūryasiddhānta* schemes. After the change to the Thandeikta calendar the Burmese changed some of the parameters involved, in general following those of the modern *Sūryasiddhānta*.

**Keywords:** History of astronomy, calendars, eclipse calculations, longitude of the Sun, longitude of the Moon, longitude of the planets, Burmese astronomy, Thai astronomy

## 1 LONGITUDES OF THE SUN AND THE MOON AND THE LATITUDE OF THE MOON

The mean longitude of the Sun in the Thai and original Burmese calendars[1] is calculated using the excess of solar days in units of 1/800th of a day at the beginning of the solar year, adding the number of elapsed day of the year multiplied by 800 and dividing by 24350. The quotient gives the zodiacal sign (*rasi*) involved.[2] The remainder is divided by 811, the quotient is the degrees in the sign (*angsa*), the remainder is further divided by 811, the quotient is the arc minutes (*lipda*). The reason for the numbers 24350 and 811 is the following: a zodiacal sign contains 30 degrees that is 1/12th of 360°. A year contains 292207 parts in units of 1/800th of a day. Dividing this by 12 we get 24350, i.e. one zodiacal sign corresponds to 24350 parts of 1/800th of a day. Then one degree corresponds to 24350/30 = 811. The calculation procedure is only approximate but accurate enough and typical of the integer kind of calculations with ‗magical' numbers that is used in Burma and Thailand. There are 3 arc minutes extra subtracted from the mean longitude of the Sun, the reason is given below.

Table 1: Solar and lunar *chayas*.

| Angle | Solar Equation | Lunar Equation |
|---|---|---|
| 0 | 0 | 0 |
| 15 | 35 | 77 |
| 30 | 67 | 148 |
| 45 | 94 | 209 |
| 60 | 116 | 256 |
| 75 | 129 | 286 |
| 90 | 134 | 296 |

The true longitude of the Sun, $L_{true}$, can mathematically be written as a function of the mean longitude, $L_{mean}$, by

$$L_{true} = L_{mean} - \arcsin[e \times \sin(L_{mean} - w)], \qquad (1)$$

where $e$, the eccentricity of the Sun, is 14/360, and $w$ is the longitude position of the apogee of the Sun, taken as 80°. These are both *Sūrya-siddhānta* values (Billard, 1971). The second term of this expression, the equation, is interpolated using a table given in arc minutes, the *chaya* (see Table 1), with entries for every 15 degrees of angle in the first quadrant, 0–90°. Due to the symmetry of the sine function only values in the first quadrant are needed in the table though the equation is negative in the third and fourth quadrants.

The Thai and Burmese computations for the lunar longitude may appear confusing because the Southeast Asian calendarists effortlessly switch between using solar day and lunar day units (and sometimes get confused themselves). For example, in the Burmese and in La Loubère's (1691) description the *avoman*, $a$, is computed from the elapsed lunar days or *tithis*, $t$, by the relation

$$a = [(t \times 11) + 650] \bmod 703, \qquad (2)$$

while, in Wisandarunkorn (1997) and Faraut (1910), it is computed using the elapsed *ahargaṇa*, $h$, by

$$a = [(h \times 11) + 650] \bmod 692. \qquad (3)$$

The *avoman* is the excess over whole *tithis* for elapsed solar days, or *ahargaṇa*. A *tithi* is 692/703 of a solar day and thus 11/703 shorter than a solar day in units of a solar day. On the

other hand, a solar day is 703/692 *tithi* and thus 11/602 *tithi* longer in units of a lunar day. The difference between the two expressions above is that the first one gives the *avoman* in units of 1/703 of a solar day while the second expression gives the *avoman* in units of 1/692 of a lunar day.

In a similar way *tithis* can be converted to *ahargaṇa* and *vice versa* with the two relations:

$t = h + [(h \times 11) + 650]/692,$ (4)
and $h = t - [(t \times 11) + 650]/703.$ (5)

The *tithis* measure the elongation of the Moon from the Sun, each *tithi* corresponding to 360/30 = 12° of elongation. The *avoman* is a measure of the fraction of the *tithi*. The scheme for converting the *avoman* into a fractional lunar elongation of the day is to take the *avoman*, divide by 25, add the *avoman* to the quotient and divide by 60. This will give the fractional lunar elongation in degrees. The procedure is equivalent of multiplying the *avoman* by 1.04 and dividing by 60. In the first relation above, equation (2), the maximum value of the *avoman* is 703, corresponding to a solar day. If we multiply this by 1.04 and divide by 60 we get 12.185°, which is almost exactly the daily movement of the Moon, 360/29.530583 = 12.191°. Using the second expression for the *avoman*, a value of 692 corresponds to one *tithi*, and 692 × 1.04/60 = 11.995°, which again is almost exactly the correct value of 12° for the movement of the Moon in one *tithi*. Thus, by using the number 25 the fractional lunar longitude of the day is ‗magically' produced. If the number of whole elapsed *tithis* multiplied by the daily *tithi* motion of 12° is added to this fractional longitude, the result is the mean elongation of the Moon from the Sun. Alternatively, if the *ahargaṇa* multiplied by the Moon's motion in a solar day can be added, the result will be the same.

Adding the mean solar longitude to the elongation longitude will give the mean lunar longitude. Then 40 minutes of arc are routinely subtracted from the mean longitude of the Moon as with the 3 minutes of arc were subtracted from the mean longitudes of the Sun. These corrections have no clearly obvious purpose, but an explanation can be found. The mean daily motion of the Sun is 59′ and that of the Moon is 790′. Thus, 3′ of the Sun corresponds to 24 × 3 /59 = 1.22 hours of time and 40 of the Moon corresponds to 24 × 40/790, also 1.22 hours of time. Converted to geographical longitude where 15° corresponds to one hour, 1.22 hours equate to 18.3° in longitude, which is roughly the longitude difference between Ujjain, the prime meridian of India and Western Burma, and indicates that the subtracted minutes of arc is a correction introduced when the Indian calculation methods were transferred to Burma (something already that the French astronomer Cassini noticed). One notes, however, that the operation survived in Faraut's (1910) version of the scheme, whose home ground was Cambodia, whereas the adjustment properly applies only to Burma. If it had indeed been required, the adjustment would have needed to be twice the applied amount to apply to Cambodia. It is clear, then, that the function of the adjustment was lost sight of, but it nonetheless continued to be integral to the reckoning.

The longitude of the lunar apogee is not fixed but is determined by the *uccabala*, and the current value has to be calculated using the following formula:

$uccabala = (ahargana + 2611) \bmod 3232.$ (6)

The *uccabala* is converted to the angular position of the apogee, where 3232 days correspond to 360°. In the original *Sūryasiddhānta* it is assumed that the lunar apogee (*mandocca*) makes 488219 revolutions in 1577917800 days, i.e. the period is 1577917800/488219 = 3231.9878 days.

The true longitude of the Moon is calculated in the same way as for the Sun but now with the *Sūryasiddhānta* lunar eccentricity 31/360 (Billard, 1971) and using the current value of the lunar apogee. The equation is again given in terms of a table or *chaya* (see Table 1).

The Burmese Thandeikta scheme for the Sun and the Moon is a little different from that of the Makaranta. The mean longitude in minutes of arc of the Sun is calculated from the expression

$L_{mean} = (1000 \times k_0 + 800000 \times sutin - 6 \times sutin)/13528,$ (7)

where $k_0$ is the New Year *kyammat* and *sutin* is the number of elapsed days of the solar year. The last two terms express the mean daily solar movement (800,000 − 6)/13528 = 59.136162 minutes of arc.

The mean longitude of the Moon is calculated, as before from the *avoman* but now with the expression

$L_{mean} = tithis \times 12 \times 60 + (avoman + 7/173 \cdot \times avoman) - 52',$ (8)

which gives the longitude in arc minutes. The factor 7/173 ≈ 1/24.714 is very nearly the same as 1/25 that is used in the Makaranta scheme. The extra correction of 52′ is partly a geographical longitude correction from Ujjain and partly a secular correction. The lunar apogee is calculated using the approximation that the daily motion of the apogee is 3 × 1800/808 = 6.68317′, which is effectively the same as the Makarata and Arakanese value.

The Thandekta equations are calculated ac-

Table 2: Thandeikta solar and lunar *chayas*.

| Angle (°) | Solar Equation | Lunar Equation |
|---|---|---|
| 0 | 0 | 0 |
| 3.75 | 9 | 20 |
| 7.5 | 17 | 40 |
| 11.25 | 26 | 60 |
| 15 | 34 | 79 |
| 18.75 | 43 | 98 |
| 22.5 | 51 | 116 |
| 26.25 | 58 | 134 |
| 30 | 66 | 152 |
| 33.75 | 73 | 169 |
| 37.5 | 80 | 185 |
| 41.25 | 87 | 200 |
| 45 | 93 | 214 |
| 48.75 | 99 | 228 |
| 52.5 | 104 | 241 |
| 56.25 | 109 | 252 |
| 60 | 113 | 262 |
| 63.75 | 117 | 272 |
| 67.5 | 121 | 280 |
| 71.25 | 124 | 287 |
| 75 | 126 | 293 |
| 78.75 | 128 | 297 |
| 82.5 | 129 | 300 |
| 86.25 | 130 | 302 |
| 90 | 131 | 303 |

cording to the modern *Sūryasiddhānta* where the eccentricities vary in size,

$$e = e_0 - 20/(360 \times 60)\sin(L_{mean} - w), \quad (9)$$

and $e_0$ is 14/360 for the Sun and 32/360 for the Moon. The solar apogee is fixed at longitude 77° 18′. This gives the following *chayas* for the Sun and the Moon (see Table 2). This table is also divided into smaller steps of 3.75°.

The latitude of the Moon is computed by assuming an inclination of the lunar orbit of 4.5° and assuming that plane geometry can be used. If the distance from the node is $\Delta$, this would give the lunar latitude $\beta$ as

$$\beta = \Delta \times \tan 4.5° \approx \Delta \times 4.5 \times \pi/180 \approx \Delta \times 4.5/60. \quad (10)$$

It is also used when the tangent of a small angle is approximately equal to the angle expressed in radians and the value of $\pi$ has been set to 3.

## 2 DAY LENGTH AND *LAGNA*

Day length and *lagna*, the ascendant or rising sign, are closely related. The *lagna* is used in Southeast Asian astrological records to give the time of day. Day length (Thai: *thinpraman*) can be computed using the concept of ascensional difference, that is the excess of daytime over the day length at the equinoxes. At the equinoxes the Sun for any location on the Earth moves during the daytime in the sky in a 180° section of a great circle, and the day length is 12 hours. At other times of the year the Sun will move in a parallel circle and the day length will be either longer or shorter. The ascensional difference *A*, can be computed by the formulae

$$\sin\delta = \sin\varepsilon \times \sin\lambda \quad (11)$$

$$\text{and } \sin A = \tan\varphi \times \tan\delta, \quad (12)$$

where $\lambda$ is the ecliptic longitude of the Sun, $\delta$ the declination of the Sun, $\varepsilon$ is the obliquity of the ecliptic (in Indian tradition assumed to be 24°), and $\varphi$ is the geographical latitude of the location on Earth. The day length (in degrees) is then calculated by 180° + 2*A*. Note that *A* is negative when the declination of the Sun is negative.

Table 3: The day length and oblique ascension of the Sun for a geographical latitude of 15° 45′.

| Sun's Longitude | Oblique Ascension | Differences | Thinpraman |
|---|---|---|---|
| 0 | 0 | 244 | 1800 |
| 30 | 244 | 272 | 1868 |
| 60 | 516 | 312 | 1922 |
| 90 | 828 | 334 | 1944 |
| 120 | 1162 | 326 | 1922 |
| 150 | 1488 | 312 | 1868 |
| 180 | 1800 | 312 | 1800 |
| 210 | 2112 | 326 | 1732 |
| 240 | 2438 | 334 | 1678 |
| 270 | 2772 | 312 | 1656 |
| 300 | 3084 | 272 | 1678 |
| 330 | 3356 | 244 | 1732 |
| 360 | 3600 | – | 1800 |

The Burmese and Thai astronomers used the time units *nadi*/*nayi*/*nati* and *vinadi*/*vinati*/*bizana*. There are 60 *nadi* in a day and night and each *nadi* is equal to 60 *vinadi*, i.e. there are 3600 *vinadi* in a day and night. This makes the conversion from the angular measure degrees to *vinadi* very simple, as it is achieved by a multiplication of the degrees by 10.

The *lagna* is a concept inherited from India and is the rising sign of the ecliptic at a given time. In Western astrology it is the ascendant. In order to calculate the lagna another quantity is needed, the oblique ascension, $\Omega$. The scheme to calculate the oblique ascension is the following:

Given the longitude of the Sun we can calculate its right ascension, $\alpha$, by

$$\tan\alpha = \tan\lambda \times \cos\varepsilon. \quad (13)$$

The oblique ascension of the Sun is then the difference between the right ascension and the ascensional difference

$$\Omega = \alpha - A. \quad (14)$$

Table 3 shows the day length and oblique ascension of the Sun for a geographical latitude of 15° 45′ where the argument in the left column is the longitude of the Sun. At sunrise the *lagna* of the Sun is of course the longitude of the Sun. As the Sun rises the oblique ascension will increase by the time converted to degrees, and the longitude of the *lagna* can be obtained by inverse interpolation from the table for oblique ascension.

Figure 1 shows the Thai way of displaying these tables. The circle is divided into twelve sectors, one for each zodiacal sign, with Aries at the top and the other signs following counter-

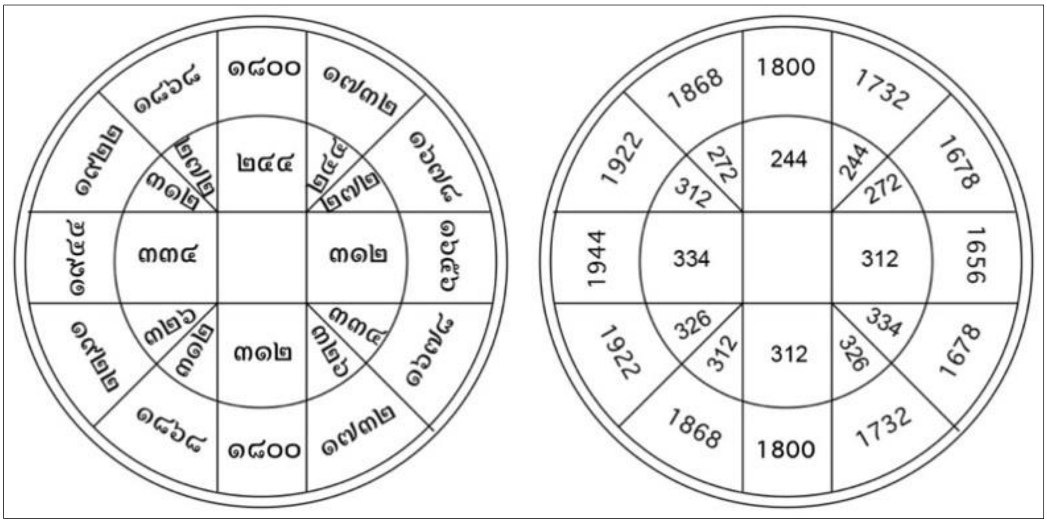


Figure 1: Thai day length and oblique ascension table (after Wisandarunkorn, 1997: 165).

clockwise around the circle. The outer band of numbers presents the day lengths in *vinadi*, the inner band shows the differences in oblique ascensions. Intermediate day lengths are found by interpolation. The oblique ascension is found, as an example will show, by starting at the top of the figure, adding the numbers in the inner band up to the given sign, and then interpolating the final addition.

Worked example: Find the daylength when the longitude of the Sun is 30° and the geographical latitude is 15° 45′. Using formula (11) we get $\delta$ = 11.73°. Formula (12) gives $A$ = 3.36° and day length 186.8° or 1868 *vinadi*. This is also the result from the figure.

Worked example: Find the *lagna* using Figure 2 when the Sun's longitude is 70° = 2 × 30° + 10° and the time is 1 *nadi* = 60 *vinadi* (24 minutes) after sunrise. We first add differences 244 + 272 = 516 for the two signs up to 60°. The next difference is 312 and interpolating with the remaining 10° we get an additional 312/3 = 104 and a total of 516 + 104 = 620. Adding the time after sunrise, 60, we get 680. We now start subtracting the numbers in the figure as far as we can go: 680 – 244 – 272 = 164. The next difference is 312 and corresponds to a longitude difference of 30° thus interpolating we get (30 × 164)/312 = 15° 46´. The *lagna* is 60 + 15° 46′ = 75° 46′.

Figure 2 illustrates the concepts of ascensional difference, day length and oblique ascension. The figure shows the celestial sphere as seen from a place on Earth. The sky seems to rotate along an oblique axis that makes an angle of the geographical latitude with the horizontal plane. The origin of the equatorial system is $\gamma$, the vernal equinox. The Sun, S, is supposed to be just rising. In the equatorial coordinate system it has a right ascension, the angle $\gamma$CP and a declination, the angle PCS. The point P has the same right ascension as the Sun at S. The angle

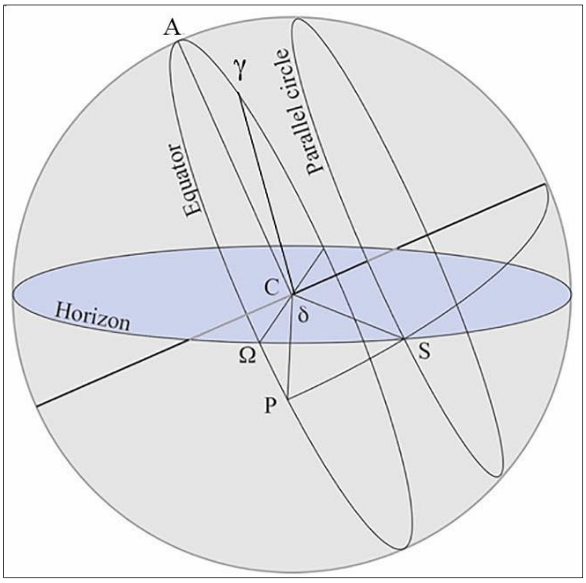


Figure 2: Ascensional difference, day length and oblique ascension (diagram: Lars Gislén).

PCA is half the day length and the angle $\Omega$CP is the ascensional difference. Subtracting the ascensional difference $\Omega$CP from the right ascension of the Sun, $\gamma$CP gives the angle $\gamma$C$\Omega$, the oblique ascension of the Sun.

There is sometimes a simplified way of calculating the *lagna* by a standardised table (Table 4) for the rising times of the different zodiacal

Table 4: Rising times.

| Sign | Rising Time(*nadis*) | Rising Time (Minutes) |
|---|---|---|
| Aries | 5 | 120 |
| Taurus | 4 | 96 |
| Gemini | 3 | 72 |
| Cancer | 5 | 120 |
| Leo | 6 | 144 |
| Virgo | 7 | 168 |
| Libra | 7 | 168 |
| Scorpio | 6 | 144 |
| Sagittarius | 5 | 120 |
| Capricorn | 3 | 72 |
| Aquarius | 4 | 96 |
| Pisces | 5 | 120 |

Table 5: Planetary periods.

| Mahayuga | Days | *Sūryasiddhānta* | Thai |
|---|---|---|---|
| 1577917800 | Rotations | Period | Period |
| Mercury | 17937000 | 87.969995 | 8797/100 |
| Venus | 7022388 | 224.69818 | 224.7 |
| Mars | 2296824 | 686.999875 | 687 |
| Jupiter | 364220 | 4332.32058 | 12997/3 = 4332.33 |
| Saturn | 146564 | 10766.0667 | 10766 |
| Rahu | 232226 | 6794.7508 | 6795 |
| Ketu | | | 679 |

Figure 3: A Thai amulet showing Rahu eating the Sun (Gislén Collection).

sign given for instance in Wisandarunkorn (1997: 12). It is not true for any location but has the advantage that it can be used for any location.

Example: Find, using the standardised table, the *lagna* when the Sun's longitude is 70° (i.e. 10° into Gemini, thus 2 × 30° + 10°) and the time is 5 *nadi* (120 minutes) after sunrise. We first add the rising times for Aries and Taurus, 5 + 4 = 9. The next rising time is 3 *nadi*, of which we require one third and by interpolating get an additional 1 *nadi* and a total of 10 *nadi*. Adding the time after sunrise, 5 *nadi* as given, we get 15 *nadi*. We now start subtracting the numbers in the table as far as we can go: 15 – 5 – 4 – 3 = 3 *nadi*. The next rising time is 5 *nadis* and corresponds to a longitude difference of 30° thus interpolating we get (30 × 4)/5 = 24°. The *lagna* is 90°+ 24° = 114°, Cancer 24°.

## 3 PLANETARY LONGITUDES

For the planets the quite complicated computational scheme in *Sūryasiddhānta* is used (Billard, 1971: 76). In Faraut (1910: 214–221) the description of the scheme for Mars uses seven pages of text. The mean longitudes of the planets are computed using somewhat simplified values for the *Sūryasiddhānta* periods, see Table 5. The Thandeikta scheme uses 20383/3 = 6794.333 for the period for Rahu, the Moon's ascending node.

Table 6: Planetary parameters.

| Planet | *e* | $\rho$ | *w* |
|---|---|---|---|
| Mercury | 28/360 | 132/360 | 220° |
| Venus | 14/360 | 260/360 | 80° |
| Mars | 70/360 | 234/360 | 110° |
| Jupiter | 32/360 | 72/360 | 160° |
| Saturn | 60/360 | 40/360 | 240° |

Rahu was considered to be a demon that devoured the Sun during eclipses (Figure 3). It is equivalent to the Western notion of the Dragon's Head. It has a retrograde constant motion. Ketu, while borrowed from Hindu astrology, is different from its original version. Hindu astronomy considers Rahu and Ketu to be the ascending and descending lunar nodes, respectively, but Southeast Asian astrology considers Ketu to be a theoretical planet orbiting the Earth with a speed ten times that of Rahu, moving in the same retrograde direction and with only astrological significance.

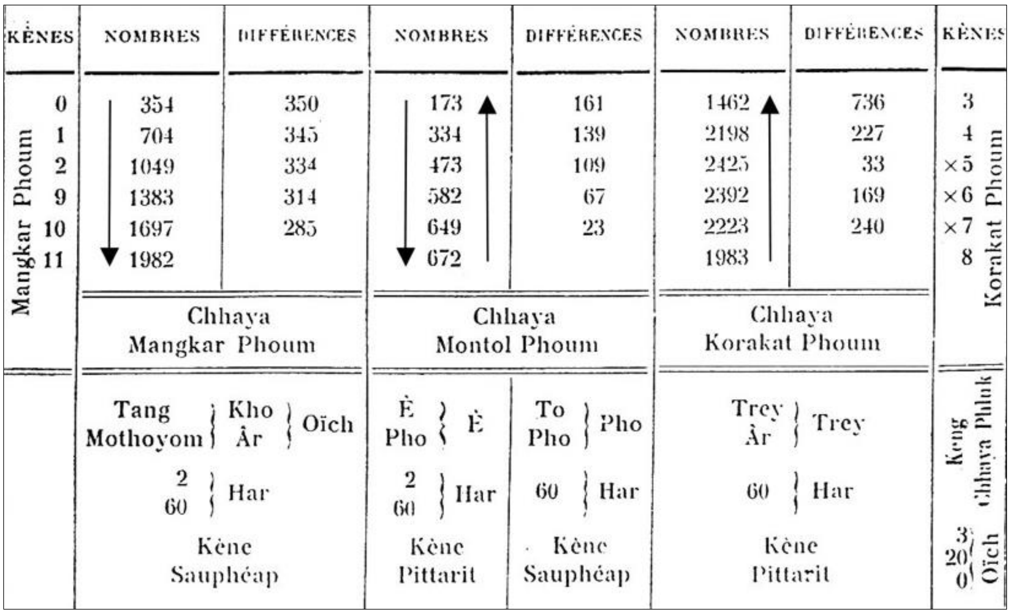
The true longitudes of the five planets are computed with the complicated scheme below (Billard, 1971; Faraut, 1910). The modern mathematical formulation is given with comments. The input parameters are: the mean longitudes of the planet, *L*, and Sun, *S*. Each planet also has three fixed parameters: the eccentricity, *e*, the radius, $\rho$, of the excentre, and the longitude of the apogee, *w*. These parameters are shown in Table 6.

The true longitude of an outer planet is then computed using the scheme below:

1) $\eta = S - L$, the elongation
2) $c_1 = \arcsin(\rho \times \sin\eta/\sqrt{[(1 + \rho \times \cos\eta)^2 + (\rho \times \sin\eta)^2]}$, first correction
3) $w_1 = w - c_1/2$, first corrected apogee
4) $\alpha_1 = L - w_1$, corrected anomaly
5) $c_2 = \arcsin(e \times \sin \alpha_1)$, second correction
6) $w_2 = w_1 + c_2/2$, second corrected apogee
7) $\alpha_2 = L - w_2$, second corrected anomaly
8) $c_3 = \arcsin(e \times \sin\alpha_2)$, third correction
9) $L_1 = L - c_3$, corrected mean longitude
10) $\eta_1 = S - L_1$, corrected elongation
11) $c_4 = \arcsin(\rho \times \sin\eta_1/\sqrt{[(1 + \rho \times \cos\eta_1)^2 + (\rho \times \sin\eta_1)^2]}$, fourth correction
12) $L_{true} = L_1 + c_4$, the true longitude.

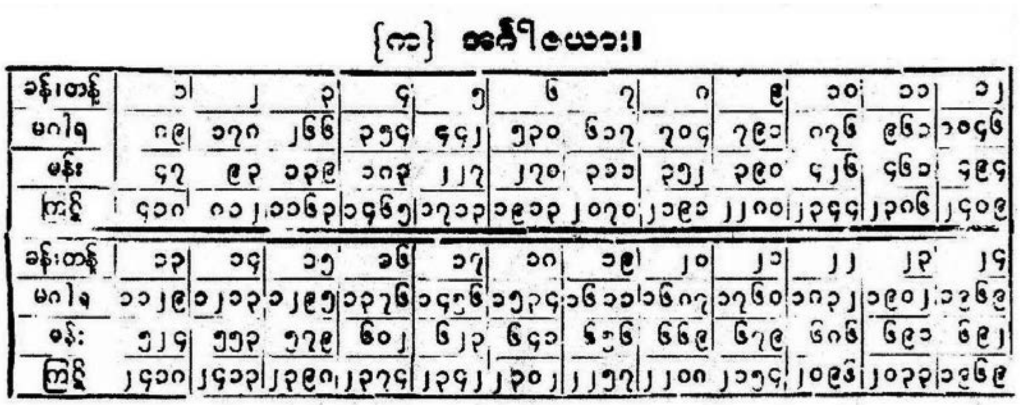
For the inner planets the roles of the Sun and the planet are interchanged.

The mathematical functions, in (5) and (8), and in (2) and (11) are given by Faraut (1910) in the form of *chayas* for each planet, albeit with many printing errors and lacunae. The first func-



| KÈNES | NOMBRES | DIFFÉRENCES | NOMBRES | DIFFÉRENCES | NOMBRES | DIFFÉRENCES | KÈNES |
|---|---|---|---|---|---|---|---|
| 0 | 354 | 350 | 173 | 161 | 1462 | 736 | 3 |
| 1 | 704 | 345 | 334 | 139 | 2198 | 227 | 4 |
| 2 | 1049 | 334 | 473 | 109 | 2425 | 33 | ×5 |
| 9 | 1383 | 314 | 582 | 67 | 2392 | 169 | ×6 |
| 10 | 1697 | 285 | 649 | 23 | 2223 | 240 | ×7 |
| 11 | 1982 | | 672 | | 1983 | | 8 |
| Mangkar Phoum | Chhaya Mangkar Phoum | | Chhaya Montol Phoum | | Chhaya Korakat Phoum | | Korakat Phoum |
| | Tang Mothoyom } Kho Âr } Oïch; 2 / 60 } Har; Kène Saupheáp | | È Pho } È; 2 / 60 } Har; Kène Pittarit | To Pho } Pho; 60 } Har; Kène Saupheáp | Trey Âr } Trey; 60 } Har; Kène Pittarit | | Keng Chhaya Phluk; 3 / 20 / 0 } Oïch |

Figure 4: Grand *chaya* for Mars (after Faraut, 1910: 216).



| Argument | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| → | 89 | 178 | 266 | 354 | 442 | 530 | 617 | 704 | 791 | 876 | 961 | 1046 |
| ↔ | 47 | 93 | 139 | 183 | 227 | 270 | 311 | 352 | 390 | 426 | 461 | 494 |
| ← | 418 | 812 | 1163 | 1465 | 1713 | 1913 | 2070 | 2191 | 2280 | 2344 | 2386 | 2409 |
| **Argument** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** |
| → | 1129 | 1213 | 1295 | 1376 | 1456 | 1534 | 1611 | 1687 | 1760 | 1832 | 1902 | 1969 |
| ↔ | 524 | 553 | 579 | 602 | 623 | 641 | 656 | 669 | 679 | 686 | 691 | 692 |
| ← | 2418 | 2413 | 2398 | 2374 | 2342 | 2302 | 2257 | 2208 | 2154 | 2096 | 2033 | 1969 |

Figure 5: Thandeikta *chaya* for Mars with transcription (after Anonymous, 1953).

tion is symmetric in the intervals [0, 90°] and [90°, 180°] such that its value for an angle in the first interval is the same as for the complementary angle in the second interval and it is only necessary to table it for the first interval, the *montol* table. The second function does not have this symmetry and is given as two separate tables, then *mangkar* and *korakat*, one for each angular interval. Figure 4 shows these tables for Mars.

The symmetric function is located in the top middle with values for 15°, 30°, 45°, 60°, 75°, and 90° in the direction of the arrows. The table then continues in descending order for angles 90° to 180°. The asymmetric function is located to the top left (0°–90°) and right (90°–180°) as shown by the arrows. The two bottom values, 1982 and 1983, should have been the same, showing that Faraut (1910) was ignorant of the astronomical background of these tables.

The Thandeikta scheme for calculating the true longitudes is the same as the one above but the eccentricities and radii of the excenters vary as function of the anomaly just as in the modern *Sūryasiddhānta* (Burgess, 2000) and the planetary *chayas* become different. Figure 5 shows the Thandeikta *chaya* for Mars corresponding to Figure 4 with transcription, taken from a Burmese manuscript (Anonymous, 1953). Each vertical of the twenty-four column represents 3.75°.

## 4 ECLIPSE CALCULATIONS

Eclipse calculations require the true longitudes of the Sun and the Moon. Also, the position of

the lunar node has to be calculated in order to calculate the ecliptic latitude of the Moon, which is essential to know when determining the size and duration of the eclipse. These quantities are calculated for two sequential days that cover the eclipse. By interpolation, the time is found when the Sun and the Moon coincide in longitude for a possible solar eclipse or when the longitude of the Sun and the Moon differ by 180° for a possible lunar eclipse. If the Moon is sufficiently close, less than 12° to either the ascending or the descending node there can be an eclipse. A solar eclipse requires corrections for parallax. Due to the finite and different distances of the Moon and the Sun from the Earth there will be an apparent change in the relative positions of the Sun and the Moon for an observer on the Earth (topocentric) relative to the positions observed from the centre of the Earth (geocentric) that has to be taken into account and corrected for. Once these corrections are calculated and applied, the circumstance of the eclipse, sizes of the solar, lunar and shadow disks, eclipse duration, and the times for the start and end of the eclipse can be computed (Eade and Gislén, 1998; Gislén, 2015).

## 4.1 Parallax in Longitude

Parallax corrections are only necessary for the calculation of a solar eclipse. A lunar eclipse looks the same for all observers on the Earth where the Moon is above the horizon and the eclipse events are simultaneous for all observers and can because of this fact be used to determine geographical longitude differences between locations. It was an important tool for the French Jesuits who visited Siam in CE 1685 when they determined the longitude of Lopburi using the lunar eclipse of 11 December 1685 (Gislén, 2004; Gislén et al., 2018).

### 4.1.1 Thailand and Early Burma

Figure 6 shows the situation at the time of a geocentric conjunction between the Sun and the Moon. It is assumed that the Moon and the Sun move in the equatorial plane of the Earth and that we see the Earth from the North Pole. The Earth, like the Moon and the Sun, rotates anti-clockwise around C in the figure. At the geocentric conjunction, the Moon, M and the Sun, S, lie on a straight line from the centre of the Earth, C. However, for the observer at O, the sight lines to the Moon and the Sun will not coincide: there is an angle between the lines OM and OS. This is the parallax that will displace the Moon and the Sun relative to each other. In general, the parallax $\pi$, of an object is given by $\pi = \pi_0 \times \sin H$, where $\pi_0$ is the horizontal parallax, the parallax when the hour angle $H$ is 90° and the celestial object is at the horizon. The horizontal parallax in the *Sūryasiddhānta* astronomical system is $\pi_M = 53'$ for the Moon and $\pi_S = 4'$ for the Sun, actually defined as the angle they move in 4 *nadi*. After some time, the Earth has rotated the angle $\Delta H$ and the observer, now at O‘, will see that the Moon and the Sun have moved a little counter-clockwise and that the new positions of the Moon, M‘ and the Sun, S‘ will coincide as seen from O‘ and that there is a topocentric conjunction. The angle $\alpha$ is given by

$$\alpha = H + \Delta H - v_M \times \Delta H/21600' + \pi_M \times \sin(H + \Delta H), \qquad (15)$$

$$\alpha = H + \Delta H - v_S \times \Delta H/21600' + \pi_S \times \sin(H + \Delta H), \qquad (16)$$

using the new positions M‘ and S‘ for the Moon and the Sun respectively, and assuming that the radius of the Earth is small compared to the distances to the Moon and the Sun. Here $v_M$ and $v_S$ are the angular daily motions of the Moon and the Sun expressed in minutes of arc. Setting these two expressions equal we get

$$\Delta H = 21600' \times (\pi_M - \pi_S)/(v_M - v_S) \times \sin(H + \Delta H). \qquad (17)$$

If now the mean values for the daily motions are inserted, $v_M = 790'$, $v_S = 59'$, we get

$$\Delta H = 24° \sin(H + \Delta H). \qquad (18)$$

This relation can be found also in al-Khwārizmī (Neugebauer, 1962). It is a transcendental equation for $\Delta H$, the observer‘s correction to the geocentric conjunction time, and has to be solved by iteration. First $\Delta H$ is set to zero in the right member of the equation, and a new value for $\Delta H$ is computed, this value is inserted in the right member and so on. This iteration converges

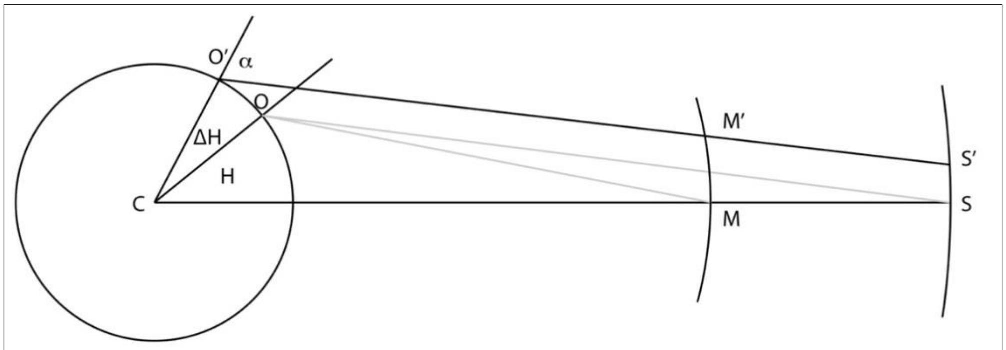



Figure 6: Parallax in longitude (diagram: Lars Gislén).

Table 7: Comparison of longitudinal parallax.

| Time/ *nadis* | 1st Iteration | 2nd Iteration | 3rd Iteration | 4th Iteration | Wisandarunkorn (1997) | Faraut (1910) |
|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | - |
| 1 | 6 | 8 | 9 | 9 | 9 | - |
| 2 | 11 | 15 | 17 | 18 | 18 | - |
| 3 | 16 | 23 | 25 | 26 | 26 | 22 |
| 4 | 21 | 29 | 32 | 33 | 32 | 29 |
| 5 | 26 | 35 | 38 | 39 | 37 | 35 |
| 6 | 31 | 40 | 43 | 43 | 43 | 40 |
| 7 | 35 | 45 | 47 | 47 | 46 | 44 |
| 8 | 39 | 48 | 49 | 50 | 49 | 47 |
| 9 | 43 | 50 | 51 | 51 | 50 | 50? |
| 10 | 46 | 52 | 52 | 52 | 51 | 51? |
| 11 | 48 | 53 | 53 | 53 | 53 | 52? |

converges very rapidly. Expressing $H$ in the time unit *nadi* (1 *nadi* = 6°) and converting $\Delta H$ to the movement in minutes of arc in longitude of the Moon by multiplying by the factor 790/360, these iterations generate the values shown in Table 7 (where the minutes of arc have been rounded to the nearest integer). The parallax correction is negative for times before noon and positive after noon.

This table compares the iteration result with two of the sources for Thai eclipse calculations. As can be seen, Wisandarunkorn (1997) agrees very well with the third and fourth iteration. Faraut's (1910) table lacks the first few values and is clearly defective at the end. Making his values start at three *nadi* and deleting some of his last values gives something similar to the second iteration.

### 4.1.2 Late Burma

The recipe to calculate the longitudinal parallax from the hour angle of the eclipsed bodies is given in a Burmese manual (U Thar-Thana, 1937). Figure 7 shows an extract from the manual text. Here is an English translation of the text in Figure 7:

*Method to compute the parallax correction.*

> Convert the *nadi* and *vinadi* to *vinadi*. Set down the *vinadi* in two places. Multiply the upper one by 7 to make the numerator. Add 600 to the lower one to make the divisor. Divide the numerator and the denominator, the quotient is the parallax correction in *nadi*. The remainder, multiplied by 60 is the *vinadi* ….

The parallax in longitude is called *lambanata* (လမ္ဗနတ). Burgess (2000) gives the Sanskrit term as *lambana* (लम्बन), meaning ‗hanging down'. In mathematical language the calculation scheme can be written as:

$N = 7 \times V/(600 + V),$ (19)

where $V$ is the hour angle (time from noon) expressed in the time unit *vinadi* and $N$ is the parallax time correction in *nadi*. $V$ is always taken to be positive, but the resulting *nadi* correction is added to the conjunction time if the conjunction occurs after noon otherwise it is subtracted. In order to compare it with the Thai parallax above we convert the *vinadi* into *nadi* and the time correction into minutes of arc and get Table 8 to compare with Table 7.

Figure 7: Extract from a Burmese eclipse manual (after U Thar-Thana, 1937: 22).

If we compare the Thai and Burmese variants of parallax with the result from modern astronomy the Burmese formula is remarkably good (Gislén, 2015). In reality the correction varies a little with the longitude of the Sun, but the Burmese formula gives good mean values.

## 4.2 Parallax in Latitude

### 4.2.1 Thailand

A rather precise theoretical expression used in Indian and early Islamic astronomy for the parallax in latitude $\pi_\beta$ of an object in the ecliptic is the expression (Neugebauer, 1962):

$\pi_\beta = (\pi_M - \pi_S)\sin(\delta_N - \varphi),$ (20)

Table 8: Burmese parallax correction in longitude.

| Time/nadi | Correction |
|---|---|
| 0 | 0 |
| 1 | 8 |
| 2 | 15 |
| 3 | 21 |
| 4 | 26 |
| 5 | 31 |
| 6 | 35 |
| 7 | 38 |
| 8 | 41 |
| 9 | 44 |
| 10 | 46 |

where $\delta_N$ is the declination of the nonagesimal, the highest point of the ecliptic, and $\varphi$ the geographical latitude. Using standard trigonometrical formulae, and the relation between declination and longitude, this can be written as

$$\pi_\beta = (\pi_M - \pi_S)(\sin\varepsilon\cos\varphi\sin\lambda_N - \cos\delta_N\sin\varphi). \tag{21}$$

Here the longitude of the nonagesimal is $\lambda_N = \Lambda - 90°$, where $\Lambda$ is the longitude of the ascendant, the *lagna*, and $\varepsilon$ is the obliquity of the ecliptic, in Indian astronomy assumed to be 24°. The Thai scheme splits this expression into two terms. The first of these terms, $(\pi_M - \pi_S)\sin\varepsilon\cos\varphi\sin\lambda_N$, can be simplified using an approximation. For locations in Mainland Southeast Asia the geographical latitudes are such that the cosine term is close to 1 and varies little with the geographiical latitude. The value used for the factor $(\pi_M - \pi_S)\sin\varepsilon\cos\varphi$ is set at 19′, giving $\varphi$ the value of 17.6°, presumably a kind of mean geographical latitude for the region. The function for this parallax term is given as a very crude table {9′, 16′, 19′} for arguments 30°, 60° and 90°.

The second term $\pi' = (\pi_M - \pi_S)\cos\delta_N\sin\varphi$ still depends on the declination of the nonagesimal. As $\delta_N$ lies in the interval [0, 24°], the value

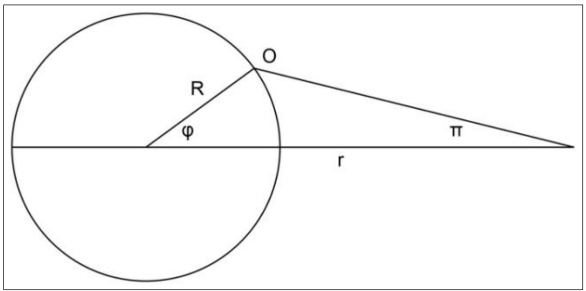



Figure 8: Geographical parallax (diagram: Lars Gislén).

of $\cos\delta_N$ will lie in the interval [0.91, 1], and the factor $(\pi_M - \pi_S)\cos\delta_N$ will lie in the interval [44.6′, 49′]. Without providing any explanation, Wisandarunkorn (1997) gives a value of 13′44″ for this second parallax term. The anonymous manuscript (Anonymous MS.) uses the value 13′ 40″. Faraut's description (1910: 176) of how to compute this parallax, 8″, is cryptic: „On retranche toujours 2, de 50 = 48, que l'on multiplie avec 2 = 96, que l'on divise par 12 = 8.“ However, there is a possible explanation, which is based on a crude approximation. Assume that the Moon and the Sun move in the equatorial plane and are located in the meridian of the observer. Figure 8 then describes the situation for the Moon. Assuming that the combined parallaxes of the Moon and the Sun are small relative to the geographical latitude, the geographical parallax is given by

$$\pi = (\pi_M - \pi_S)\sin\varphi = 49'\sin\varphi. \tag{22}$$

Wisandarunkorn (1997) gives his tables for day length and *lagna* for a geographical latitude of about 16° N. Inserting this in the formula gives a parallax of 13′ 30″. Faraut (1910) gives a table of day lengths for a geographical latitude for 9° 40′ N. Inserting this value in the formula gives a parallax of 8′ 14″. Both of these numbers are close to the values actually used by these sources.

### 4.2.2 Burma

The Burmese handling of the parallax in latitude is more sophisticated. The time from noon in *nadi* is multiplied by 6 in order to convert it to degrees, the hour angle. The result is then added to the longitude of the Sun. The result is a rather good approximation of the longitude of the nonagesimal $\lambda_N$, at least for locations in Burma. A table is then used to calculate the declination $\delta_N$ of the nonagesimal, using the correct relation $\sin\delta_N = \sin\varepsilon\sin\lambda_N$ with $\varepsilon = 24°$, the Indian obliquity. The parallax in latitude is then calculated using the correct expression $\pi_\beta = (\pi_M - \pi_S)\sin(\delta_N - \varphi)$, also with help of a table, where $\pi_M - \pi_S = 49'$. The agreement with a modern calculation is very good (Gislén, 2015).

## 5 ANALYSIS OF A THAI TRADITIONAL SOLAR ECLIPSE CALCULATION

The solar eclipse of 18 August 1868 is one of the more interesting events in Thai astronomical history and also one of the most important eclipses in the history of solar physics (see Orchiston, 2020). The duration of the totality was exceptionally long and it was the first solar eclipse where spectroscopic observations were made, leading to the discovery of helium (Nath, 2013). It was observed at several locations on the Earth, from Aden in the west to Indonesia in the east, by Austrian (Aden), English (India), German (Aden and India), French (India and Siam), and Dutch (Indonesia) astronomers (see Launay, 2012; Mumpuni et al., 2017; Orchiston et al., 2017). One of the French contingents of astronomers observed the eclipse from Wah-koa in Siam (under the black spot in Figure 9) in the presence of King Rama IV (Mongkut) of Siam (Orchiston and Orchiston, 2017). King Rama IV (Saibejra, 2006) had personally made calculations for this eclipse using Western methods, not being satisfied with the traditional way of calculating eclipses. Figure 9 shows a modern calculation of the centrality path of the eclipse. The black dot shows the size of the area on the Earth where the eclipse was total, and the red circle the area in which it was partial at the time of the totality in Wah-koa. It was total at that location about twenty minutes before noon, local time.

For eclipses the traditional Thai calculations use a special set of parameters for the Sun and the Moon. In the ordinary day-to-day calculations in South-East Asia the astronomical parameters were based on the *Sūryasiddhānta* and

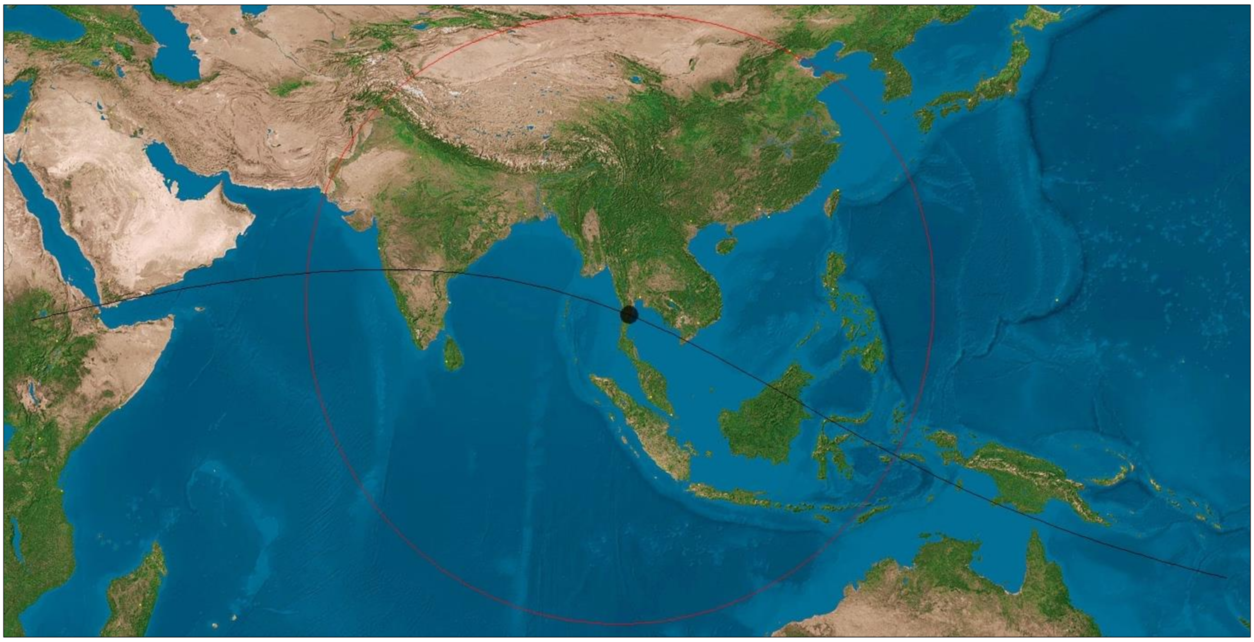


Figure 9: The solar eclipse 18 August 1868 (diagram: Lars Gislén).

midnight was used as the time reference. It is evident from the source manuscripts that the South East Asian astronomers used such day-to-day calculations to spot the occurrence of an eclipse and then switched to a more accurate set of parameters to perform the calculation of the eclipse circumstances. The parameters used for eclipse calculations are shown in Table 9 (Gislén and Eade, 2001). The precision given is 1/10000000 of a minute of arc.

The solar parameters except for the epoch longitude are exactly the values used in the *Aryabhatiya* (Billard, 1971: 77). Also, the use of 6:00 hours as the time reference points to the *Aryabhatiya*. However, the lunar parameters differ slightly from Aryabhāta's values. Billard (ibid.) describes a Hindu calendar that was introduced around CE 1000 and mentioned in the anonymous *Grahacarānibandhanasamgraha* (Haridatta, 1954). In Billiard's notation it is called k.(GCNib)B. The calendar scheme makes the following amendments to Aryabhāta's lunar parameters (Billard, 1971: 143):

Moon's longitude – ($S$ – 444) × 9/85′, and
Moon's apogee – ($S$ – 444) × 65/134′, and
Node – ($S$ – 444) × 13/32′,

where $S$ is the Śaka year. A simple check shows that this correction generates lunar parameters that precisely match those used by the South-east Asian calendarists.[3]

Also, the epoch values correspond exactly to the values generated by the change above with the exception of that for the lunar apogee: 17651′ instead of 17641′; the Thai symbols for 4 and 5 look very similar and are easily confused. Finally, the epoch chosen for the eclipse calculations is exactly the day 1550000 current since the epoch of the Kaliyuga, 18 February 3102 BCE, certainly not a coincidence.

By a lucky coincidence, we have a Thai calculation of the 18 August 1868 solar eclipse of Wah-koa and shown in Figure 10 that was drawn from an anonymous Chiang Mai manuscript (Anonymous MS). The calculation follows exactly the traditional calculation scheme for a solar eclipse with the 63 steps given by Wisandarunkorn (1997: 190–204). The calculation in the manuscript is shown as a series of numbers accompanied by a Thai technical label that in most cases has a Sanskrit or Pali origin. A detailed transcription of the numbers in the manuscript is given here in the Appendix, in Section 12.1. Below is merely a crude layout of the calculation scheme.

The Thai date of the eclipse is written at the top of the page, 3 1/– 10 1230 Chulasakharat. The first digit 3 stands for the weekday, Tuesday. The second and third digits indicate that the day is the first of the waxing Moon in month 10, which is the month Bhadrapada in the numbering of Central Thailand. The last number is the year in the Chulasakharat Era. The first line of the calculation shows the number of years elapsed since the epoch, 725. Line 3 shows the value 265098, the number of elapsed days from the epoch. The following lines 4–15 show the

Table 9: Basic eclipse parameters.

| Epoch CE 10 October 1142 = 28 Asvina 504 Chulasakarat Era | | |
|---|---|---|
| Basic Eclipse Parameter | Epoch longitude (arc mins) | Mean daily motion (arc mins) |
| Solar longitude | 12260 | 59.1361716 |
| Lunar longitude | 11339 | 790.5810032 |
| Solar apogee | 4680 | 0 |
| Lunar apogee | 17461 | 6.6818670 |

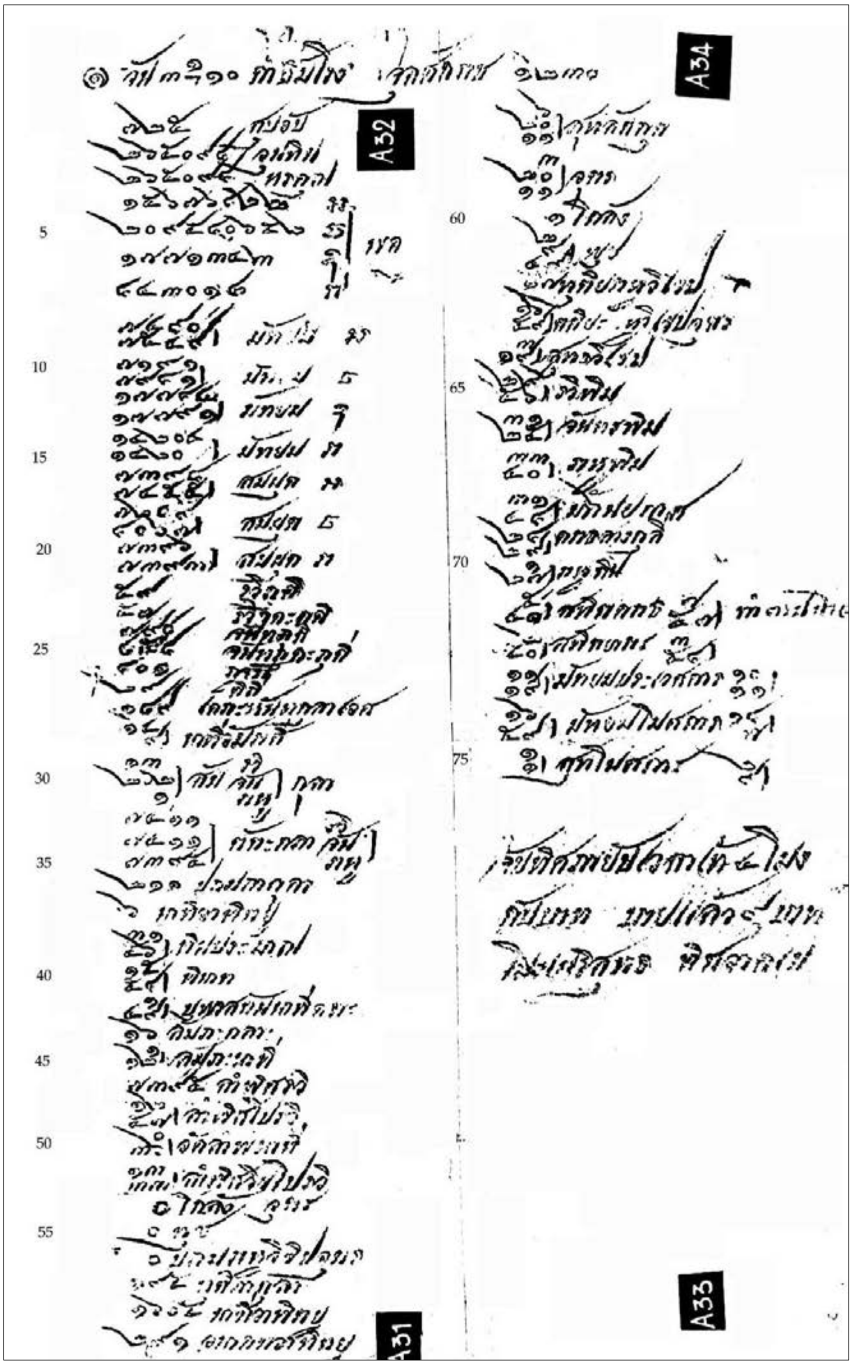



Figure 10: Traditional Thai solar eclipse calculation.

calculated mean longitudes of the Sun, the Moon, the Moon‘s apogee, and the node respectively for this day and the day following, the eclipse occurring within this time. Lines 16–26 calculate the true longitudes, the true elongation and the true daily motions. After having checked if an eclipse is possible, line 28, the conjunction time and longitudes are interpolated in lines 29–35. The eclipse is assumed possible if the Moon is within 12° of the lunar node, both for solar and lunar eclipses. The lengths of day and night are calculated in lines 36–41. In lines 42–45 the longitude parallax corrections are calculated and in 46–49 applied to the conjunction time and conjunction longitude. Lines 50–57 calculate the first approximation to the lunar latitude using the Moon‘s distance from the node. After having calculated the *lagna* and the nonagesimal (lines 58–63), the parallax corrections to the latitude are calculated to give the apparent latitude, 3′ 19″, line 64. Lines 65–70 calculate the sizes of the solar and lunar disks and the size of the eclipse. Finally, the last lines compute the eclipse duration and the times of the start and end of the eclipse.

The calculation of the semiduration of the eclipse uses a scheme that is special for Thai eclipse calculations. It has not been possible to determine the origin of this scheme, but it is very crude and may be quite ancient. The lunar

latitude in minutes of arc is subtracted from 31′, the sum of the mean lunar and solar disk radii, and with this argument Table 10 is entered and the duration interpolated.

For the eclipse, the computed lunar latitude is 3′ 19″. Subtracting this from the sum of the mean solar and lunar radii, 31′, we get 31′ – 3′ 19″ = 27′ 41″. Interpolation in the table gives the duration as 5 *nadi* 41 *vinadi*, the actual value given in the manuscript.

There is a similar table to use for lunar eclipses where the lunar latitude is subtracted from 54′, which is the sum of the mean radii of the disks of the Moon and the mean shadow disk radius, where the disk radius of the shadow is taken to be 2.5 times that of the radius of Moon's disk. The table used for lunar eclipses is shown as Table 11. Faraut (1910) has a similar table, but for unknown reasons it has slightly different numbers.

According to the traditional calculation above for Bangkok, the eclipse is not total. The reason is that the parallax correction in latitude is too large, the real effective parallax correction in latitude being only of the order of 2′. The geocentric lunar latitude is about –2′, which gives a topocentric latitude of zero and a total eclipse. The reason for the error is that in order to compute the *lagna* correctly it is necessary to use the tropical longitude of the Sun, i.e. including the precession, which in this case is 21° 51′, and this is not done. The neglect of the precession in the calculation can be due either to its having fallen out of the instructions or that the instructions were out-dated. Recalculation with the precession included gives indeed a total eclipse.

## 6 A BURMESE LUNAR ECLIPSE CALCULATION

Burmese solar eclipse calculations are much more complex (Gislén, 2015). They use the modern *Suryasiddhānta* parameters. The precision of the calculation is in seconds of arc, precession is included, and the duration of the eclipse is calculated using an iterative scheme that corrects for the changing ecliptic latitude of the Moon during the eclipse.

The layout for a lunar eclipse is shown in Figure 11. The first two numbers in the top left column give the year, first one in the Burmese era, 1296 (၁၂၉၆), then in the Kaliyuga era 5035 (၅၀၃၅). The Gregorian date of the eclipse is 26 July 1934. The following lines show the new year *kyammat,* 85 (၈၅), the new year weekday (1 (၁) = Sunday), and the number of elapsed days of the year, 102 (၁၀၂). Then follow the calculated mean longitudes of the Sun, the Moon, the apogee and the node. The longitudes are also given here with a precision of seconds of arc.

Table 10: Solar eclipse duration.

| Argument | Duration/*Nadi* |
|---|---|
| 0 | 0 |
| 1 | 1 |
| 3 | 2 |
| 6 | 3 |
| 12 | 4 |
| 20 | 5 |
| 31 | 6 |

Then the true longitudes are calculated, top centre column, lines 2 and 3, and the true daily motion and the true motion in elongation, right column line 2. The rest of the top right column is devoted to a computation of the tropical longitude of the Sun, day length and the noon shadow (see Section 7 below).

The bottom left column calculates the conjunction times and the conjunction longitudes. Knowing the angular distance between the Moon and the node, in this case the ascending node, the lunar latitude is calculated assuming an inclination of 4.5″ of the lunar orbit relative to the ecliptic. This value of the inclination of the lunar orbit is standard in many Indian astronomical texts.

Also standard in both Thailand and Burma is the calculation of the sizes of the lunar and shadow disks. These sizes are assumed to be proportional to the daily motion, *v,* of the stellar object, i.e. the diameter, *D*, is assumed to be

$$D = D_{mean} \times v_{true}/v_{mean}. \qquad (23)$$

Given the apparent radii, *r* and *R*, of the Moon and the shadow respectively and the lunar latitude, $\beta$, the first approximation to the (half) duration, *d*, is calculated using the Pythagorean theorem:

$$d = \sqrt{\{(R - r)^2 - \beta^2\}} \qquad (24)$$

for the total phase and

$$d = \sqrt{\{(R + r)^2 - \beta^2\}} \qquad (25)$$

for the partial phase. If $R - r < \beta$, the first relation will not give a real number and the eclipse is only partial. The geometry of the eclipse is shown in Figure 12.

The latitude of the Moon is not constant during the eclipse and using the computed dura-

Table 11: Lunar eclipse duration.

| Argument | Duration/Nadis |
|---|---|
| 0 | 0 |
| 1 | 1 |
| 2 | 2 |
| 4 | 3 |
| 7 | 4 |
| 11 | 5 |
| 15 | 6 |
| 21 | 7 |
| 28 | 8 |
| 40 | 9 |
| 54 | 10 |

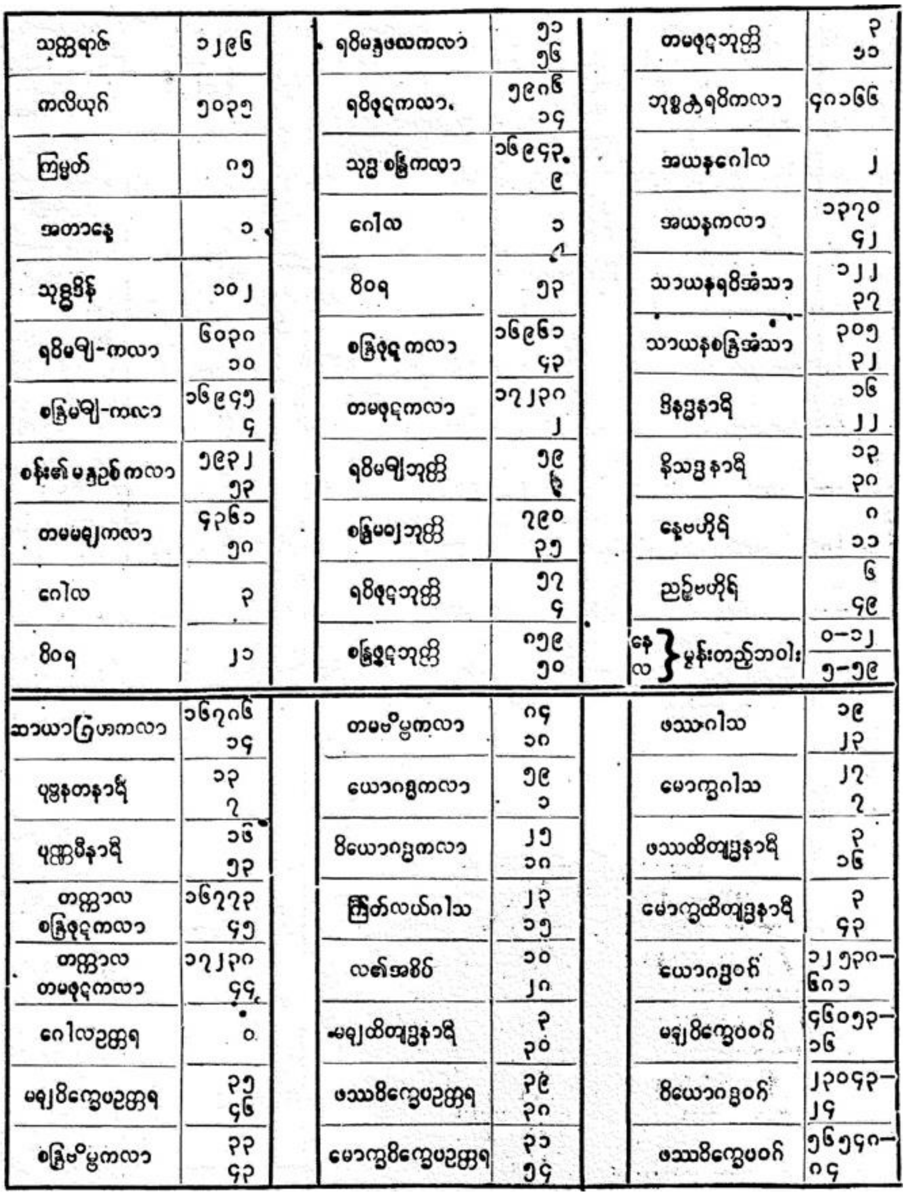


Figure 11: Burmese lunar eclipse calculation.

tion as a first approximation, new values of the lunar latitude are computed for the beginning and end of the eclipse and new semi-durations are calculated and taken as final. This calculation is correct mathematically, is very similar to the calculations done in the modern *Sūryasidddhānta* (Burgess, 2000), and is much more sophisticated than the Thai calculation.

This lunar eclipse was partial. The beginning of the eclipse was not visible from Yangoon as the Moon had not yet risen, and the middle of the eclipse occurred about 10 minutes after sunset. Comparing the calculated times with a modern ephemeris the agreement is very good, the error being only about five minutes.

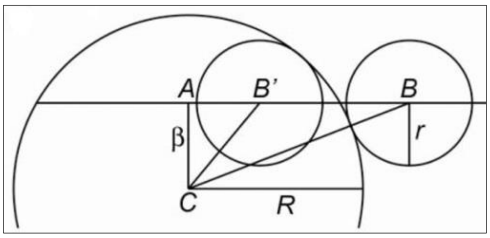



Figure 12: Eclipse geometry (diagram: Lars Gislén).

## 7 SHADOW CALCULATIONS

These calculations are specific for Burma where there are instructions in astronomical manuals of how to do such calculations (Gislén and Eade, 2014). However, there are a few examples also from the Thai region:

> … in the third month, on the fourth day of the waning moon … when the shadow (of the gnomon) cast by the morning sun measured fifteen feet, in the rksa of Citra, in the year seven hundred thirty-one of the Era.

> … the eighth day of the day of the waxing moon of the first month, Thursday, the auspicious day and time, in the afternoon when the shadow of the gnomon marked exactly six padas.

It is difficult to evaluate these records as there are too many unknown facts. The height of the gnomon is not known, and being a Thai record it is not known if the solar longitude and day length are corrected for precession. It seems that the shadow calculations or observations had mostly astrological significance and were of little practical use. Some records even give ‗Moon shadows'. They appear in horoscopes, but also accompany eclipse calculations (Gislén, 2015).

Primitive shadow calculations appear already in Mesopotamia (Neugebauer, 1975(1): 544; Ôhashi, 2011). More sophisticated are the Indian calculation schemes using the formula

$$d/(2t) = (s - s_0)/G + 1, \quad (26)$$

where $s_0$ is the noon shadow length, $G$, the gnomon height, $s$ the shadow length, $t$ the time from sunrise or sunset, and $d$ the day length (Abraham, 1981). The same formula can also be found in the *Romakasiddhānta* in Varahamihira's *Pañcasiddhantika* (Neugebauer, 1970; Sastry, 1993). Using a half day length $D = d/2$ and measuring time $T$ from noon $T = D - t$, we can rewrite this expression as it is used in the Burmese calculations:

$$s = s_0 + G \times T/(D - T). \quad (27)$$

It is easy to see that this expression makes sense. At noon, $T = 0$, and $s = s_0$, the noon shadow. At sunrise or sunset, the denominator is zero and the shadow becomes infinite as it should.

However, in an astronomically correct calculation the factor $G$ is not constant but will depend on the longitude $\lambda$ of the Sun and the geographical latitude $\varphi$, as well as on the gnomon height. There is also a dependence on the time $T$ from noon. In the Burmese scheme the dependence on the geographical latitude is neglected since this variation is not excessive in the Mainland Southeast Asia area (Mauk, 1971; Thi, 1936). The noon shadow depends on the declination of the Sun (in turn being a function of the solar longitude), and on a geographical latitude $\varphi$, which cannot be neglected there. The half day length will depend on the longitude of the Sun and the geographical latitude. We are then left with the formula

$$s = s_0(\lambda,\varphi) + G(\lambda,T) \times T/(D(\lambda,\varphi) - T). \quad (28)$$

The calculation of the noon shadow, $s_0$, and the half day length is done by having a table for a set of towns in Southeast Asia. Table 12 below shows a table for Yangoon with a transcription. What is tabulated is the difference between the noon shadow and the equinoctial noon shadow, the *bawa* (ဘဝါ).

The number to the far right, 126, is the equinoctial noon shadow for Yangoon, using a gnomon with height $G$ = 7 subdivided into 60 subunits. The equinoctial noon shadow is $G \tan \varphi$, where $\varphi$ is the geographical latitude. Thus, $\tan \varphi = 126/420$, giving $\varphi = 16° 42'$, which is close to the modern geographical latitude 16° 52′.

The column on the left in the table stands for multiples 1, 2, and 3 of 30° of the solar latitude. The next column is used for calculating the day length, and shows the excess *vinadi* to be added or subtracted to the equinox half day length of 15 *nadi* or 900 *vinadi*. In this column, due to symmetry, multiple 2 is equivalent to 4, 8, and 10, and multiple 1 is equivalent to 5, 7, and 11. The numbers in the last two columns show the *bawa*. You start going up the first column then back down, continue up the last column and then back down remembering that there is a hidden row with zeros at the top for solar longitude 0° and 180°. The *bawa* is to be added or subtracted from the equinoctial shadow, depending on the declination of the Sun.

For the multiplier $G(\lambda,T)$ there is a special double-entry table for longitude and *nadi* from noon, as shown in the upper Table 13. The column numbers are the *nadi* from noon.

Example. Calculate the shadow three *nadi* after noon in Yangoon when the Sun's longitude is 60° = 2 × 30°. The excess day length from Table 13 is 69 and as the Sun is north of the equator the excess is added to the equinox half day length of 900 *vinadi* to give 969 *vinadi*. The *bawa* is 155. As the Sun is moving north in declination the noon shadow becomes shorter and we should take the difference between the *bawa* and the equinoctial shadow to get the noon shadow: 155–126 = 29. From top Table 13, with arguments 60° for the Sun (Taurus) and

Table 12: Shadow table for Yangoon.

| | | | | | |
|---|---|---|---|---|---|
| | ၁ | ၃၆ | ၉၀ | ၁၀၁ | |
| ရန်ကုန်မြို့ | ၂ | ၆၉ | ၁၅၅ | ၁၉၄ | ၁၂၆ |
| | ၃ | ၇၇ | ၁၈၀ | ၂၃၅ | |

| | | | | | |
|---|---|---|---|---|---|
| | 1 | 36 | 90 | 101 | |
| Yangoon | 2 | 69 | 155 | 194 | 126 |
| | 3 | 77 | 180 | 235 | |

Table 13: Multiplier tables (after Thi, 1936).

| Nadis | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Capricorn | | 61 | 124 | 168 | 216 | 251 | 280 | 307 | 325 | 338 | 345 | 349 | 350 | 325 | | | |
| Aqu | Sag | 63 | 133 | 176 | 220 | 250 | 280 | 305 | 321 | 331 | 335 | 337 | 337 | 310 | | | |
| Pis | Sco | 79 | 134 | 187 | 232 | 267 | 291 | 309 | 320 | 324 | 325 | 320 | 312 | 301 | 288 | | |
| Aries | Libra | 89 | 162 | 236 | 283 | 312 | 330 | 339 | 340 | 335 | 328 | 317 | 303 | 286 | 267 | 268 | |
| Tau | Virgo | 178 | 304 | 363 | 395 | 408 | 415 | 402 | 391 | 375 | 313 | 338 | 318 | 296 | 309 | 251 | |
| Gem | Leo | 571 | 599 | 582 | 563 | 590 | 509 | 484 | 456 | 430 | 409 | 375 | 349 | 322 | 301 | 270 | 229 |
| Cancer | | 455 | 522 | 539 | 530 | 515 | 494 | 471 | 450 | 427 | 402 | 372 | 351 | 326 | 302 | 267 | 241 |

| Nadis | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Capricorn | | 69 | 128 | 178 | 219 | 254 | 281 | 304 | 321 | 335 | 346 | 354 | 359 | 363 | | | |
| Aqu | Sag | 69 | 127 | 176 | 216 | 249 | 275 | 296 | 312 | 324 | 333 | 339 | 343 | 346 | | | |
| Pis | Sco | 72 | 132 | 181 | 220 | 250 | 273 | 290 | 302 | 310 | 315 | 317 | 317 | 316 | 315 | | |
| Aries | Libra | 92 | 165 | 220 | 258 | 284 | 301 | 311 | 316 | 318 | 317 | 313 | 309 | 303 | 296 | 288 | |
| Tau | Virgo | 168 | 273 | 329 | 356 | 368 | 371 | 369 | 363 | 355 | 346 | 335 | 325 | 313 | 302 | 290 | |
| Gem | Leo | 499 | 532 | 524 | 507 | 487 | 467 | 446 | 427 | 407 | 389 | 371 | 354 | 337 | 321 | 306 | 291 |
| Cancer | | 449 | 506 | 509 | 498 | 481 | 464 | 445 | 427 | 409 | 391 | 374 | 358 | 342 | 327 | 312 | 298 |

three *nadi*, we get the multiplier 363, where 3 *nadi* is equal to 180 *vinadi*. Using formula (25) we get the shadow of a 420 unit gnomon as

$$s = 29 + 363 \times 180/(969 - 180) = 112. \qquad (29)$$

By inverting the relation it is possible to get an expression for the multiplier

$$G(\lambda,T) = (s - s_0) \times (D(\lambda,\varphi) - T). \qquad (30)$$

The bottom Table 13 shows the result for $G(\lambda,T)$ from a modern calculation for geographical latitude 22°, with a result that is rather similar to the Burmese table. However, it is not known how the Burmese constructed their table.

Using equation (28) it is possible to solve for the time after noon:

$$T = D(s - s_0)/(G + s - s_0). \qquad (31)$$

This can be used to find the time, given the shad-ow length—a procedure that is found in some manuscripts. However, the quantity $G$ is itself a function of time. The problem is solved by iteration, first $G$ is set to 7 (or 420) and a preliminary time, $T$, is computed. A new $G$ is taken from the multiplier table using this time and a second approximation time can be calculated that can be used to find a new $G$, and so on.

In the Burmese calculations the scheme is also used to calculate Moon shadows by, instead of using $D$ for half the length of the night, letting $T$ be time from midnight and using the longitude of the Moon. This neglects the fact that the Moon does not move on the ecliptic. Such Moon shadows are obviously purely artificial, and show that the system had become a kind of ‗number magic'.

## 8 PRECESSION

For the shadow and day length, and also for *lagna* correct calculations, it is necessary to use the tropical longitude of the Sun, i.e. to take precession into account. However, it seems that Thai calculations ignore precession, something that seems very probable also for the earlier Burmese Makaranta calculations. The Burmese Thandeikta scheme uses the Indian model for precession that assumes that the correction for precession is a zig-zag function with an amplitude of 27° and a period of 7200 years. The zig-zag function starts at zero 88 years before the epoch of the Kaliyuga epoch and decreases linearly and becomes –27° after 1800 years. It then increases linearly to +27° for 3600 years, then decreases linearly to reach zero 1800 years later. In order to compute the correction for precession the following scheme is used.

The year in the Burmese era is converted to the Kaliyuga era by adding 3739. The epoch constant of 88 years is added. The result is divided by 1800 and the remainder is saved. The quotient tells which part of the zig-zag function that is actual. For all reasonable historic eras this part is where this function is positive and rising. The remainder is multiplied by 9 and divided by 10. The reason for these two numbers is that the zig-zag function increases linearly by 27° in 1800 years. 27° is 27 × 60 = 1620′. 1800 times 9/10 is precisely equal to this number. The quotient will then be the number of minutes of arc of precession. The remainder is multiplied by 6, and gives the seconds of arc of precession. The quotient is divided by 60. The quotient will be the degrees of the correction for precession, the remainder is the minutes of arc. The extreme of the zig-zag function is 1800. Multiplied by 9 and divided by 10 and then by 60 gives 27°, the amplitude of the correction for precession. The rate of precession is 27/18 = 1.5° per century, not far from the correct modern value of about 1.4° per century.

Example: Compute the correction for precession for the year 1297 in the Burmese era.

1297 + 3739 + 88 = 5124.
5124/1800 = 2, remainder 1524
1524 × 9/10 = 1471, remainder 6, 6 × 6 = 36
1471/60 = 22, remainder 51
The correction for precession is 22° 51′ 36″.

## 9 CONCLUDING REMARKS

The astronomical calculations show a great influence from Indian astronomy, in particular from the original *Sūryasiddhānta*. The later Burmese Thandeikta calculations are adaptations of the

modern *Sūryasiddhānta* and show more sophistication in, for instance, the eclipse calculations. The Thai eclipse calculations use methods taken from the Indian *Aryabhāta* canon.

## 10 NOTES

1. This is the fifth paper in a series reviewing the traditional calendars of Southeast Asia. The first paper (Gislén and Eade, 2019a) introduced the series; Paper #2 (Gislén and Eade, 2019b) was about Burma, Thailand, Laos and Cambodia, with emphasis on the first two nations; Paper #3 (Lân, 2019) was about Vietnam; and Paper #4 (Gislén and Eade, 2019c) about Malaysia and Indonesia.
2. For specialist terms used in this paper see the Glossary in Section 12.3.
3. For example, in the Aryabhata canon the lunar apogee makes 232226 rounds during a period of 4320000 years, or 1577917500 days (Billard, 1971: 78). This gives a mean motion of $232226/1577917500 \times 360 \times 60 = 6.6831950$ minutes of arc per day. The correction per year is $-65/134'$. The daily correction will then be $-65/134 \times 4320000/1577917500 = -0.0013280'$. Thus, the corrected mean motion is $6.6831950 - 0.0013280 = 6.6818670$, the value used in Table 9.

## 11 REFERENCES


Abraham, G., 1981. The gnomon in early Indian astronomy. *Indian Journal of History of Science*, 16(2), 215–218.

Anonymous [ca. 1868]. Manuscript. Chiang Mai University Library (CMUL MS 18–011) (in Thai).

Anonymous, 1953. ဆင်တဲစကားပကြျမ်း. Mandalay (in Burmese).

Billard, R., 1971. *L'astronomie Indienne.* Paris, École Française d'Extrème-Orient (in French).

Burgess, E., 2000. *The Sûrya Siddhânta*. Dehli, Motolal Banarsidass (Reprint).

Eade, J.C., and Gislén, L., 1998. “The whole Moon was eaten”: Southeast Asian eclipse calculation. *Journal of Southeast Asian Studies*, 29, 309–318.

Faraut, F.G., 1910. *Astronomie Cambodgienne*. Saigon, F.H. Schneider (in French).

Gislén, L., and Eade, J.C., 2001. South East Asian eclipse calculations. *Centaurus*, 43, 278–307.

Gislén, L. 2004. Analysis of the astronomical information in Thachard: “Voyage to Siam in the Year 1685”. *Centaurus*, 46, 133–144.

Gislén, L., and Eade, J.C., 2014. Burmese shadow calculations. *Journal of Astronomical History and Heritage*, 17, 258–266.

Gislén, L., 2015. Burmese eclipse calculations. *Journal of Astronomical History and Heritage*, 18, 53–64.

Gislén, L., Launay, F., Orchiston, W., Orchiston, D.L., Débarat, S., Husson, M., George, M., and Soonthordthum, B., 2018. Cassini's 1679 map of the Moon and French Jesuit observations of the lunar eclipse of 11 December 1685. *Journal of Astronomical History and Heritage*, 21, 211–225.

Gislén, L., and Eade, C., 2019a. The calendars of Southeast Asia. 1: Introduction. *Journal of Astronomical History and Heritage*, 22, 407–416.

Gislén, L., and Eade, C., 2019b. The calendars of Southeast Asia. 2: Burma, Thailand, Laos and Cambodia. *Journal of Astronomical History and Heritage*, 22, 417–430.

Gislén, L., and Eade, C., 2019c. The calendars of Southeast Asia. 4: Malaysia and Indonesia. *Journal of Astronomical History and Heritage*, 22, 447–457.

Haridatta, 1954. *Grahacâranibandhana*. Madras, Kuppuswami Sastri Research Institute.

Lân, T.L., 2019. The calendars of Southeast Asia. 3: Vietnam. *Journal of Astronomical History and Heritage*, 22, 431–446.

La Loubère, S., 1691. *Du Royaume de Siam. Tome 2.* Paris, Jean Baptiste Coignard (in French).

Launay, F., 2012. *The Astronomer Jules Janssen: A Globetrotter of Celestial Physics*. New York, Springer.

Mauk, 1971. *Handbook for the Calculation of Thandeikhta Horoscopes*. Mandalay (in Burmese).

Mumpuni, E.S., Orchiston, W., and Steinicke, W., 2017. J.A.C. Oudermans' observations of the 18 August 1868 and 12 December 1871 total solar eclipses from the Dutch East Indies. In Nakamura and Orchiston, 357–373.

Nakamura, T., and Orchiston, W. (eds.), 2017. *The Emergence of Astrophysics in Asia: Opening a New Window on the Universe.* Cham (Switzerland), Springer.

Nath, B.B., 2013. *The Story of Helium and the Birth of Astrophysics*. New York, Springer.

Neugebauer, O., 1962. *The Astronomical Tables of Al-Khwārizmī.* København, Historisk-filosofiske Skrifter udgivet af det Kongelige Danske Videnskabernes Selskab, 4(2).

Neugebauer, O., and Pingree, D., 1970–1971. *The Pañcasiddhantika by Varahamihira.* København, Historisk-filosofiske Skrifter udgivet af det Kongelige Danske Videnskabernes Selskab, 6(1).

Neugebauer, O., 1975. *A History of Ancient Mathematical Astronomy. Three Volumes*. Berlin, Springer.

Ôhashi, Y., 2011. On Vesāńga astronomy: the earliest systematic Indian astronomy. In Nakamura, T., Orchiston, W., Sôma, M., and Strom, R. (eds.), *Mapping the Oriental Sky. Proceedings of the Seventh International Conference on Oriental Astronomy*. Tokyo, National Astronomical Observatory of Japan. Pp. 164–170.

Orchiston, W., and Orchiston, D.L., 2017. King Rama IV and French observations of the 18 August 1868 total solar eclipse from Wah-koa, Siam. In Nakamura and Orchiston, 291–317.

Orchiston, W., Lee, E.-H., and Ahn, Y.-S., 2017. British observations of the 18 August 1868 total solar eclipse from Guntoor, India. In Nakamura and Orchiston, 771–793.

Orchiston, W. (ed.), 2020. *The Total Solar Eclipse of 18 August 1868: A Watershed Event in the Development of Solar Physics.* Cham (Switzerland), Springer.

Saibejra, N., 2006. King Mongkut: the Father of Thai Science. In Chen, K.-Y., Orchiston, W., Soonthornthum, B., and Strom, R. (eds.). *Proceedings of the*

*Fifth International Conference on Oriental Astronomy*. Chiang Mai, Chiang Mai University. Pp. 15–18.

Sastry, T.S.K., 1993. *Pañcasiddhāntika by Varahamihira*. Madras, Adyar (P.S.S.T. Science Series No. 1).

Thi, 1936. *Moon Shadow and Time Calculating Handbook*. Mandalay (in Burmese).

U Thar-Thana, 1937. *Hsin-temu thara-kjan-thi*. Mandalay (in Burmese). A pdf version of the original can be found on: http://home.thep.lu.se/~larsg/Site/UTharThaNa.pdf

Wisandarunkorn, L., 1997. *Khamphi Horasasat Thai (Profound Thai Astrology)*. Bangkok, In-print (in Thai).

## 12 APPENDICES

### 12.1 The Solar Eclipse of 18 August 1868: A Detailed Recomputation

We refer to the manuscript page shown in Figure 10. The solar and lunar equations used are given above in Table 14.

Table 14: Solar and lunar equations.

| Anomaly/arcmins | Solar equation | Lunar equation |
|---|---|---|
| 0 | 0 | 0 |
| 1000 | 37 | 87 |
| 2000 | 71 | 165 |
| 3000 | 98 | 230 |
| 4000 | 118 | 276 |
| 5000 | 128 | 298 |
| 5400 | 129 | 301 |

CS 1230, day 1, Tuesday, month 10 (Bhadrapada). The numbers to the left in the calculation below refer to steps in Wisandarunkon (1997: 190–200). Bold numbers are those found in the anonymous manuscript, and they all agree with numbers computed by following the steps in Wisandarunkorn. The numbers on the right give the line number in the manuscript.

| | | | |
|---|---|---|---|
| 1 | Unthin = **265098**, Unthin –1 = 265098 – 1 = 265097 | Days since the epoch | 2 |
| 2 | 265097 · 591361716 = 15676821\|6826452 –> **15676822** | Sun mean movement, truncated | 4 |
| 3 | 265097 · 7905810032 = 209580652\|2053104 –>**209580652** | Moon mean movement | 5 |
| 4 | 265097 · 66818670 = 1771342\|8960990 –> **1771343** | Apogee movement | 6 |
| 5 | 265097 · 31800373 = 843018\|3481181 –> **843018** | Node movement | 7 |
| 6 | (15676822 + 12268) / 21600 = 726:**7490** | Mean Sun 1 | 8 |
| 7 | 7490 + 59 = **7549** | Mean Sun 2 | 9 |
| 8 | (209580652 + 11339) / 21600 = 9702:**7191** | Mean Moon 1 | 10 |
| 9 | 7191 + 790 = **7981** | Mean Moon 2 | 11 |
| 10 | (1771343 + 17641) / 21600 = 82:**17784** | Apogee 1 | 12 |
| 11 | 17784 + 7 = **17791** | Apogee 2 | 13 |
| 12 | (843018 – 8014) / 21600 = 38:**14204** | Node 1 | 14 |
| 13 | 14204 + 3 = **14207** | Node 2 | 15 |
| 14 | (7490 – 4680) / 5400 = 0:2810 | Sun's Anomaly 1 | |
| 15 | 2810 / 1000 = 2:810 | Interpolation of | |
| | 71 + (98 – 71) · 810 /1000 = 92 | solar equation of centre | |
| | 7490 – 92 = **7398** | True Sun 1 | 16 |
| 16 | (7549 – 4680) / 5400 = 0:2869 | Sun's anomaly 2 | |
| | 2869 / 1000 = 2:869 | Interpolation of | |
| | 71 + (98 – 71) · 869 /1000 = 94 | solar equation of centre | |
| | 7549 – 94 = **7455** | True Sun 2 | 17 |
| 17 | (7191 – 17784 + 21600) / 5400 = 2:207 | Moon's anomaly 1 | |
| 18 | 207 / 1000 = 0:207 | Interpolation of | |
| | 0 + (87 – 0) · 207 / 1000 =18 | lunar equation of centre | |
| | 7191 + 18 = **7209** | True Moon 1 | 18 |
| 19 | (7981 – 17784 + 21600) / 5400 = 2:997 | Moon's anomaly 2 | |
| | 997 / 1000 = 0:997 | Interpolation of | |
| | 0 + (87 – 0) · 997 / 1000 = 86 | lunar equation of centre | |

| | | | |
|---|---|---|---|
| | 7981 + 86 = **8067** | True Moon 2 | 19 |
| 20 | 21600 – 14204 = **7396** | True node 1 | 20 |
| 21 | 21600 – 14207 = **7393** | True node 2 | 21 |
| 22 | 7549 – 7490 = **59** | Mean solar motion | 22 |
| 23 | 7455 – 7398 = **57** | True solar motion | 23 |
| 24 | 7981 – 7191 = **790** | Mean lunar motion | 24 |
| 25 | 8067 – 7209 = **858** | True lunar motion | 25 |
| 26 | 858 – 57 = **801** | Motion in elongation | 26 |
| 27 | (7209 – 7396 + 21600)/720 = **29**:533 | Distance from node <720´=12˚ | 27 |
| | 720 – 533 = 187 | Eclipse possible | |
| 28 | (7398 – 7209) / 720 = 0:**189** | Sun-Moon elongation | 28 |
| 29 | 189 · 60 / 801 = **14:9** | Conjunction time | 29 |
| 30 | 14:9 · 57 /60= **13** | Sun to go | 30 |
| 31 | 14:9 · 858/60 = **202** | Moon to go | 31 |
| 32 | 14:9 · 3/60 = **1** | Node to go (retrograde) | 32 |
| 33 | 7398 + 13 = **7411** | Sun: Conjunction longitude | 33 |
| 34 | 7209 + 202 = **7411** | Moon: Conjunction longitude | 34 |
| 35 | 7396 – 1 = **7395** | Node: Conjunction longitude | 35 |
| 36 | 7411 / 1800 = 4:**211** | Calculation of day length | 36 |
| 37 | 326 – 272 = 54, 54 · 211 / 1800 = **6** | | 37 |
| | 326 + 312 + 312 + 326 + 334 + 312 = 1922 | | |
| | 1922 – 6 = 1916, 1916 / 60 = 1916 / 60 = **31:56** | Day length | 38, 39 |
| 38 | 31:56 / 2 = **15:58** | Half day | 40, 41 |
| 39 | | Conjunction before noon | |
| | 15:58 – 14:9 = **1:49** | Time from noon | 42, 43 |
| | 9 + (18 – 9) ·49 / 60 = **16** | Parallax in longitude | 44 |
| 40 | 16 · 60 / 800 = **1:12** | Parallax time | 45, 46 |
| 41 | 7411 – 16 = **7395** | Corrected longitude | 47 |
| 42 | 14:9 – 1:12 = **12:57** | Corrected time | 48, 49 |
| 43 | 1:12 / 2 = **0:36** | Half time correction | 50, 51 |
| 44 | 14:9 – 0:36 = **13:3**3 | Time argument for lagna | 52, 53 |
| 45 | (7395 – 7395) / 5400 = **0:0** (north) | Node distance | 54 |
| | 0 · 60 / 800 = **0:0** | First latitude north | 55 |
| 46 | 7395 / 1800 = 4:**195** | Lagna calculation | 56 |
| 47 | 1800 – 195 = **1605** | | 57 |
| 48 | Enter at 5 o'clock in the duang 326 · 1605 / 1800 = **291** | | |
| 49 | 13:33 · 60 = 813, 813 – 291 = 522 | | |
| | 522 – 312 = 210 -> Lagna sign 6 | | |
| | 210 · 30 / 312 = 20:11 degrees | | |
| | **06:20:11** | Lagna | 58 |
| 50 | 6:20:11 – 3:0:0 = **3:20:11** | Nonagesimal | 59 |
| | Sign is <6 thus parallax north | Calculation of latitude | |

| | | | |
|---|---|---|---|
| | | parallax | |
| | 3/3 = **1,** second quadrant -> 6 – 3:20:11 = **2:9:49** | Complementary angle | 60, 61 |
| | Sign = **2**, parallax 16´, difference 19´–16 = 3´ | Interpolation | |
| | 3 ·9:49 / 30 + 16 = 16:59 ≈**17** | Latitude parallax correction | 62 |
| 51 | 16:59 + 0:0 = **16:59** | Second latitude north | 63 |
| 52 | 13:40 | Geographical latitude correction | |
| | 16:59 – 13:40 = **3:19** | True latitude | 64 |
| 53 | 57 · 31 / 59 = **29:56** | Solar disk diameter | 65 |
| 54a | 801 · 31 / 790 = **31:25** | Elongation diameter | 66 |
| 54b | 858 · 31 / 790 = **33:40** | Lunar disk diameter | 67 |
| 56 | (29:56 + 33:40) / 2 = **31:48** | Sum of radii | 68 |
| 57 | 31:48 – 3:19 = **28:29** | Eclipse size | 69 |
| 58 | 29:56 – 28:29 = **1:27** | Crescent > 0, not a total eclipse | 70 |
| 59 | 31 – 3:19 = 27:41 | Duration argument | |
| | 5 + (27:41–20) / (31 – 20) = 5 + 7:41 / 11 = **5:41** | Interpolation | |
| | **5:41** | Eclipse duration | 71 |
| 60 | 5:41 / 2 = **2:50** | Semiduration | 72 |
| 61,62 | 14:9 – 2:50 = **11:19,** 14:9 + 2:50 = **16:59** | Start/end of the eclipse | 73, 74 |
| 63 | 16:59 – 15:58 = **1:1** | Time from noon | 75 |

In order to compute the *lagna* correctly it would be necessary to use the tropical longitude for the Sun and the Moon, i.e. including the precession which in this case is 21° 51′ = 1311′. The tropical longitude of the Sun at the conjunction will then be 1311 + 7395 = 8706. Repeating the calculation using this value gives a total eclipse. It is not clear why precession has been neglected here.

## 12.2 Comparison of Thai Traditional Eclipse Timings

In order to compare the quality of traditional eclipse calculations we include Tables 15 and 16, which list the calculated timings of the end of totality of a number of solar and lunar eclipses found in the records. All of these eclipses were visible (weather permitting) in Southeast Asia.

The Thai month names are abbreviated by their first three letters, and the references mentioned in column 2 in both tables are as follows:

1 Astrologers Notebook, 1808.
2 Astrologers Notebook, 1808.
3 Astrologers Notebook, 1891.
4 Astrologers Notebook, MS #159.
5 Astrologers Notebook, MS #159.
6 Wisandarunkorn, 1997.
7 Faraut, 1910.
8 Anonymous [ca. 1868].

The eclipses in bold font were visible in Southeast Asia. The quality as regards to the tim-

Table 15: Comparison of solar eclipse timings.

| Date (CE) | Ref | CS Date | CS Time | Time |
|---|---|---|---|---|
| 16 May 1817 | 1, 5 | 1 Jye 1179 | 13:00 | 12:58 |
| 9 Nov 1817 | 1, 5 | 1 Kar 11794 | 06:30 | 05:50 |
| 14 Apr 1828 | 1, 3 | 1 Vai 1190 | 17:00 | 16:51 |
| 9 Nov 1836 | 1, 5 | 30 Asv 1198 | 08:00 | 06:06 |
| 9 Oct 1847 | 1, 3 | 30 Bha 1209 | 15:48 | 15:54 |
| 18 Aug 1868 | 2, 8 | 1 Bha 1230 | 11:40 | 11:49 |
| 6 Jun 1872 | – | 1 Ash2 1234 | 09:12 | 08:31 |
| 11 Nov 1901 | 6, 7 | 1 Kar 1263 | 14:58 | 15:29 |

Table 16: Comparison of lunar eclipse timings.

| Date (CE) | Ref | CS Date | CS Time | Time |
|---|---|---|---|---|
| **14 Feb 1794** | 1 | 14 Mag 1155 | 03:06 | 02:53 |
| **22 Jul 1804** | 1, 4 | 15 Ash2 1166 | 22:30 | 22:44 |
| **5 Jan 1806** | 1 | 16 Pau 1167 | 05:30 | 05:04 |
| **21 May 1807** | 1, 4 | 15 Vai 1169 | 22:48 | 22:47 |
| **2 Sep 1811** | 1, 5 | 15 Bha 1173 | 04:12 | 04:05 |
| 22 **Aug 1812** | 4, 5 | 15 Sra 1174 | 19:30 | 19:59 |
| **10 Apr 1819** | 1, 5 | 16 Cai 1181 | 17:36 | 18:02 |
| **3 Oct 1819** | 1, 5 | 14 Asv 1181 | 20:00 | 19:57 |
| **29 Mar 1820** | 5 | 15 Cai 1182 | 23:36 | 00:08 |
| **26 Jan 1823** | 1, 5 | 15 Mag 1184 | 22:12 | 22:33 |
| **25 Nov 1825** | 1, 4 | 16 Kar 1187 | 21:42 | 21:42 |
| **14 Nov 1826** | 1, 4 | 15 Kar 1188 | 20:42 | 20:27 |
| 20 Apr 1837 | 1, 3 | 16 Cai 1199 | 02:24 | 01:30 |
| 17 Feb 1840 | 1 | 15 Mag 1201 | 19:18 | 19:53 |
| 26 Jan 1842 | 1 | 15 Mag 1203 | 22:54 | 23:14 |
| 31 Mar 1847 | 1, 5 | 15 Cai 1209 | 02:36 | 03:09 |
| 24 Sep 1847 | 1, 3, 5 | 15 Bha 1209 | 20:12 | 20:03 |
| 14 Sep 1867 | 2 | 15 Bha 1229 | 05:00 | 05:35 |
| 22 May 1872 | 5 | 15 Jye 1234 | 04:30 | 05:15 |
| 27 Feb 1877 | 5 | 15 Pha 1238 | 00:24 | 00:23 |
| 13 Aug 1878 | 5 | 15 Sra 1240 | 05:24 | 05:28 |

| | | | | |
|---|---|---|---|---|
| 28 Dec 1879 | 5 | 15 Pau 1241 | 22:12 | 22:21 |
| 28 Feb 1896 | 6 | 15 Pha 1257 | 01:49 | 01:11 |
| 27 Oct 1901 | 7 | 15 Asv 1263 | 20:50 | 20:45 |

timing is quite good: Figure 13 shows the correlation. The horizontal axis is the time after midnight for the Thai prediction, the vertical axis the time according to modern calculation. A perfect correlation would be that all the eclipse timings fell on a straight line.

The deviation from modern times has a standard deviation of 30 minutes.

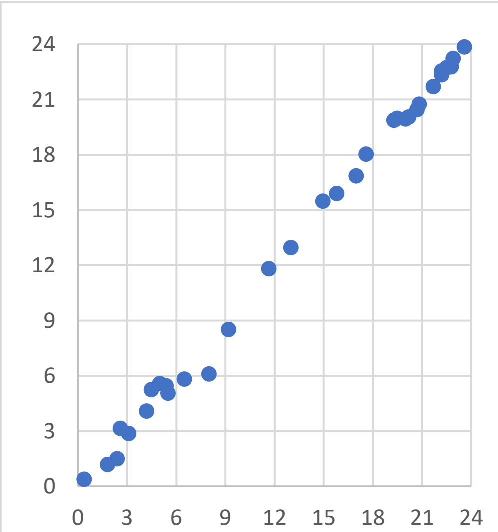



Figure 13: Eclipse timing correlations.

## 12.3 Glossary

*ahargaṇa* The number of elapsed days since the epoch.

*apogee* The location in a planet‘s orbit where it is farthest from the Earth.

*ascensional difference* The excess, positive or negative, over a half day length of six hours.

*avoman* Thai อวมาน, Burmese အဝမာန်. The excess of lunar days over solar days in units of 1/692 of a lunar day modulus 692. It increases by 11 units each solar day. It is used to determine when to add intercalary days in the calendar. Sometimes in Burmese astronomy the avoman is expressed in units of 1/703 of a solar day.

*chaya* Thai ฉายา, Burmese ဆယး. The original meaning of the word is ‗shadow‘ but it is generally used as the name of a table often being a table for the correction of mean longitude to true longitude.

*eccentricity* A quantity that measures the deviation from circularity of a planetary orbit.

*ecliptic longitude* A coordinate used together with the *ecliptic latitude* and determining a position in the zodiac.

*gnomon* A vertical pole casting a shadow of the Sun. It can be used for determining the time of the day. In Indian astronomy the gnomon often has a length of 8 units, in Burmese astronomy it is often 7 units long.

*kyammat* Burmese ကမ္ဗတ်. A quantity that gives the excess of solar days over whole solar days.

*lagna* An Indian term for the ascending zodiacal sign.

*lipta* An Indian term for minutes of arc. Of Greek origin, *λεπτον*.

*Makaranta* Burmese မကာရန္တ. A Burmese calendar similar to the Thai calendar but with a Metonic intercalation with 7 intercalary years in each 19-year period.

*mean longitude* The ecliptic longitude of a planet calculated assuming that the planet moves with constant angular velocity. This calculation is made by reference to its revolution period and to the *ahargaṇa*. Tables of correction, the *chaya* tables, are then used to convert this mean longitude to a *true longitude*.

*nadi* An Indian time measure with 60 *nadi* in a day and night. In Thai it is *nathi* and in Burmese *nayi*. It corresponds to 24 minutes of an hour.

*nonagesimal* The highest point of the ecliptic in the local sky.

*noon shadow* The length of the shadow of a vertical gnomon at noon at a particular location and at a specific date.

*oblique ascension* An astronomical quantity used in *lagna* calculations.

*parallax* A nearby object will be displaced as viewed from two different points. A simple way of experiencing parallax is to view the location of a nearby object relative to the distant horizon when viewed alternatively by the left and right eyes. As the Sun and the Moon are located at different distances from the Earth two observers on different places on the Earth will not see the Sun and the Moon in exactly the same places. In solar eclipses it is necessary to correct for parallax caused by the observer not being located at the centre of the Earth.

*Precession* Due to the gravitational influence of the Sun and the Moon on the equatorial bulge of the Earth, the rotation axis of the Earth will trace out a cone similar to that of a spinning top on a table. This will cause the vernal equinox of the ecliptic to move slowly backwards. The rate of change in tropical longitudes due to the precession of the equinoxes, about 1° in 72 years.

*rasi* An Indian term corresponding to the Western zodiacal sign.

*sutin* The number of days that have passed since the start of the given year.

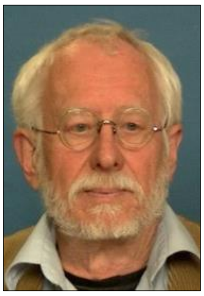
*Thandeikta* Burmese သံဒိဋ္ဌ. The calendar used from about 1200 BE (1868 CE) in Burma.

*thinpraman* Thai ทินปรามาณ. The length of half a day, which depends on the time of the year.

*tithi* Originally a time unit being a lunar day or 1/30th of a synodic month, in Southeast Asia astronomy being 692/703 of a solar day. It can also refer to the lunar day number in a month and also the relative position of the Moon relative to the Sun, the possible 360° divided into 30 tithis, each one covering 12°.

*uccabala* A measure of the position of the Moon's apogee. It increases by one unit a day to a maximum of 3232.

*vinadi* An Indian time measure being 1/60th of a *nadi*.



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# THE CALENDARS OF SOUTHEAST ASIA. 6: CALENDRICAL RECORDS

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**Abstract:** Calendrical inscriptions and chronicles are an important source of information on the history and civilisation of Southeast Asia. Most of the records are horoscopes but there are also inscriptions commemorating the foundation of temples and other important buildings, and on Buddha images. Stone inscriptions are necessarily commemorative and the event celebrated is frequently of considerable social, political, and religious importance.

**Keywords:** History of astronomy, Southeast Asia, traditional calendars, inscriptions, chronicles

## 1 INTRODUCTION: COMPUTER TOOLS

Many of the calendrical records contain redundant data, something that is very useful for dating when part of a record has been eroded or damaged.[1] For the Mainland Southeast Asian records, the Burmese and Thai calendrical procedures[2] have been implemented in a Java application, SEAC (SouthEast Asian Calendars), which can be run on both Macintosh and Microsoft Windows platforms. The use of a computer application that emulates the calendars means that the dating of inscribed records is greatly facilitated. Computing a Burmese or Thai horoscope by hand can require six hours or more. Using a computer these calculations can easily be checked almost instantly. It is possible to enter several different eras, Chulasakarat, Mahasakarat, Buddhasakarat, and Anchansakarta, which are those used in Thai chronology. For Burmese records it is possible to enter the Arakanese, Makaranta and Thandeikta eras. There is also an option to enter Western dates, sexadecimal years and days, and compute *lagna* from time and *vice versa*, and also shadow lengths. Dates can be stepped up and down by years and days and there is an option to search for selected combinations of sexagesimal years and weekdays. The application calculates true longitudes of the planets, *tithi*, *naksatra* and *yoga*, as well as the cyclic day and year, and also the calendar fundamentals, *ahargana*, *kammacabala*, *uccabala*, *avoman* and *masaken*. There is also a graphical output (*zata*/*duang*) of the calculated positions of the planets in the zodiac. A typical output of the application is shown in Figure 1.

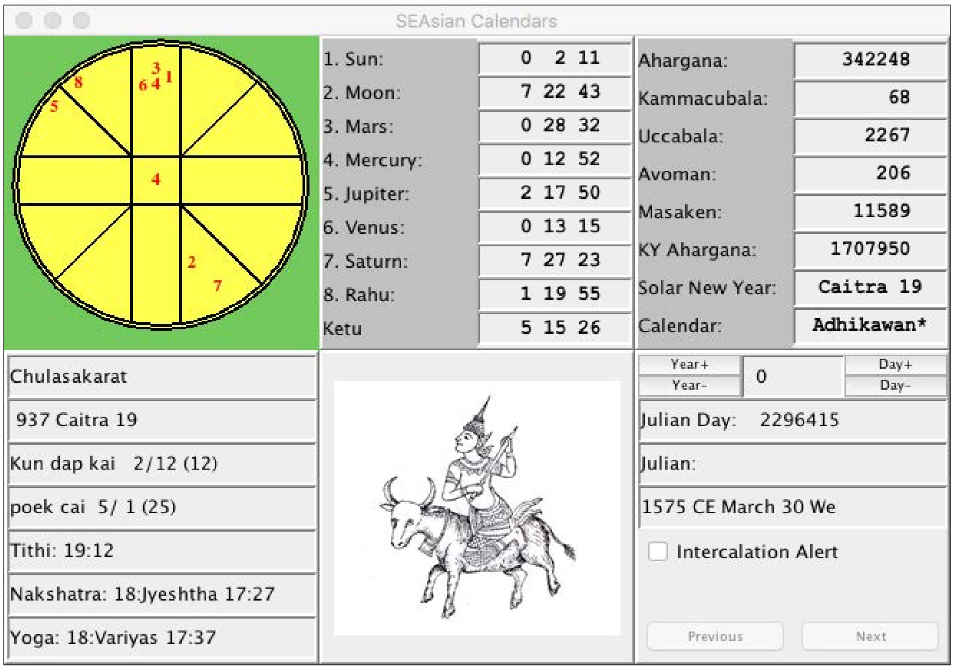
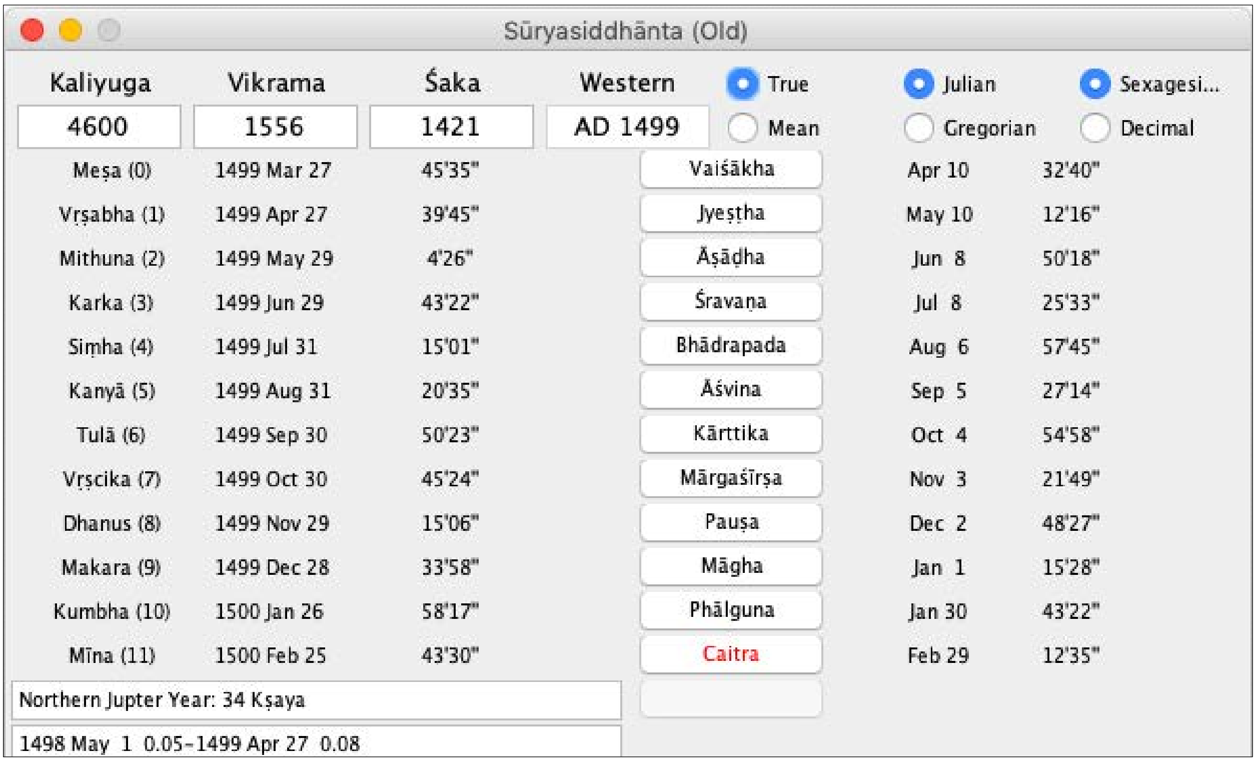



Figure 1: Application output of SEAC.



Sūryasiddhānta (Old)

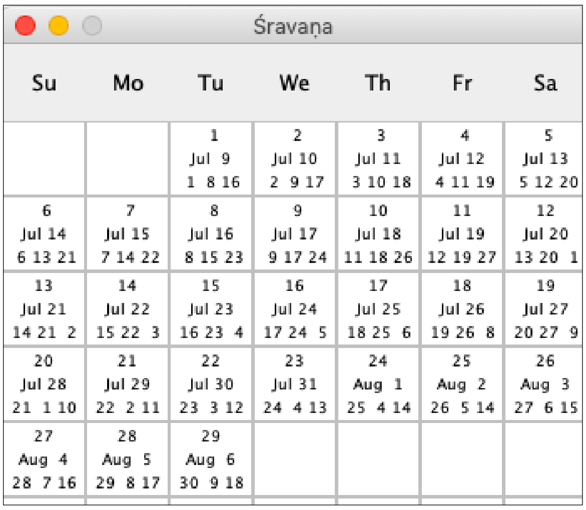
| Kaliyuga | Vikrama | Śaka | Western | True | Julian | Sexagesi... |
|---|---|---|---|---|---|---|
| 4600 | 1556 | 1421 | AD 1499 | Mean | Gregorian | Decimal |
| Meṣa (0) | 1499 Mar 27 | 45'35" | Vaiśākha | Apr 10 | 32'40" | |
| Vṛṣabha (1) | 1499 Apr 27 | 39'45" | Jyeṣṭha | May 10 | 12'16" | |
| Mithuna (2) | 1499 May 29 | 4'26" | Āṣāḍha | Jun 8 | 50'18" | |
| Karka (3) | 1499 Jun 29 | 43'22" | Śravaṇa | Jul 8 | 25'33" | |
| Siṃha (4) | 1499 Jul 31 | 15'01" | Bhādrapada | Aug 6 | 57'45" | |
| Kanyā (5) | 1499 Aug 31 | 20'35" | Āśvina | Sep 5 | 27'14" | |
| Tulā (6) | 1499 Sep 30 | 50'23" | Kārttika | Oct 4 | 54'58" | |
| Vṛścika (7) | 1499 Oct 30 | 45'24" | Mārgaśīrṣa | Nov 3 | 21'49" | |
| Dhanus (8) | 1499 Nov 29 | 15'06" | Pauṣa | Dec 2 | 48'27" | |
| Makara (9) | 1499 Dec 28 | 33'58" | Māgha | Jan 1 | 15'28" | |
| Kumbha (10) | 1500 Jan 26 | 58'17" | Phālguna | Jan 30 | 43'22" | |
| Mīna (11) | 1500 Feb 25 | 43'30" | Caitra | Feb 29 | 12'35" | |

Northern Jupter Year: 34 Kṣaya

1498 May 1 0.05–1499 Apr 27 0.08

Figure 2: Application output of HIC: Main window.

The top left panel shows a graphical layout of the position of the planets in the zodiac, the *zata* (Burmese) or *duang* (Thai) divided into twelve slots that represent the twelve zodiacal signs. The top slot is Aries, then follows, in anti-clockwise order, Taurus, Gemini and so on. The centre of the *duang* shows the weekday, in this case 4 = Wednesday. The top middle panel shows the true longitudes of the planets in format sign, degree, minutes of arc. The top right panel shows the calendar elements: *ahargana*, *kammacabala*, *uccabala*, *avoman*, and *masaken*, followed by the *ahargana* counted from the Kaliyuga epoch: 18 February 3202 BCE. Then follows the solar New Year date and the type of year, in this case it is a year with an intercalary day (*adhikawan*) and the asterisk indicates that the particular solar year is a leap year.



Śravaṇa

| Su | Mo | Tu | We | Th | Fr | Sa |
|---|---|---|---|---|---|---|
| | | 1<br>Jul 9<br>1 8 16 | 2<br>Jul 10<br>2 9 17 | 3<br>Jul 11<br>3 10 18 | 4<br>Jul 12<br>4 11 19 | 5<br>Jul 13<br>5 12 20 |
| 6<br>Jul 14<br>6 13 21 | 7<br>Jul 15<br>7 14 22 | 8<br>Jul 16<br>8 15 23 | 9<br>Jul 17<br>9 17 24 | 10<br>Jul 18<br>11 18 26 | 11<br>Jul 19<br>12 19 27 | 12<br>Jul 20<br>13 20 1 |
| 13<br>Jul 21<br>14 21 2 | 14<br>Jul 22<br>15 22 3 | 15<br>Jul 23<br>16 23 4 | 16<br>Jul 24<br>17 24 5 | 17<br>Jul 25<br>18 25 6 | 18<br>Jul 26<br>19 26 8 | 19<br>Jul 27<br>20 27 9 |
| 20<br>Jul 28<br>21 1 10 | 21<br>Jul 29<br>22 2 11 | 22<br>Jul 30<br>23 3 12 | 23<br>Jul 31<br>24 4 13 | 24<br>Aug 1<br>25 4 14 | 25<br>Aug 2<br>26 5 14 | 26<br>Aug 3<br>27 6 15 |
| 27<br>Aug 4<br>28 7 16 | 28<br>Aug 5<br>29 8 17 | 29<br>Aug 6<br>30 9 18 | | | | |

Figure 3: The HIC month window.

The bottom left panel shows the name of the era, the Southeast Asian date, the cyclic year, the cyclic day, the *tithi*, *naksatra*, and *yoga*. The *tithi* is numbered from 1 to 29/30 while the normal custom in Southeast Asia is to count the first half of the month as 1 to 15 waxing and the second half as 1 to 14/15 waning. The bottom central panel shows a picture taken from an illustration of the Khmer zodiac (Faraut, 1910: 186). The bottom right panel contains buttons for stepping year and day up and down and shows the *sutin* or the day number in the solar year. Then follow the Julian Day number (at noon) and the date in the Common Era, in this case showing the date in the Julian calendar. This will automatically switch to dates in the Gregorian calendar if the date is later than 4 October 1582 Julian, the inauguration date of this calendar. The bottom buttons are used for searches in the sexagesimal cycles. The menus of the application (not shown in the figure) allow different eras to be chosen as well as years, months, and days, among other things.

The Indonesian records are based on the Indian canons but can in practice sometimes have deviating intercalations. Here three Indian canons, the Aryabhata canon and the original as well as the modern *Sūryasiddhānta* canons have been implemented in the Java application HIC (Hindu Calendars) using the canonical Indian intercalation scheme. The Indonesian *wuku* calendar is also implemented. Figures 2–4 show typical outputs of the program.

At the top there are slots for entering the year in different eras. Below left are the solar months and the times when they start. On the right are the lunar months and their starting times, and top right are some radio buttons that govern the output format. The bottom left shows the information on the Jupiter sexagesimal cycle, although this is normally not used in the Southeast Asian chronology. A new window, the month window (Figure 3), is brought up by clicking on the relevant lunar month button.

The month window shows the layout of the days in the selected month. Each day is sequentially numbered, then the corresponding Western date is given, followed by the number triad of the *tithi*, *naksatra*, and *yoga*. By clicking on any day slot in this window, the day window is brought up (Figure 4).

The day window shows the positions of the *yoga*, *naksatra*, and *tithi* relative to the day as three parallel and horizontal lines that also show the times when they are in force. At the top are the two *karana* that are part of the *tithi* in force. Below the graphical display is the Indian date, the Western date, the *kaliyuga ahargana*, the *wuku* cyclical days and the *wuku* week and the following three buttons bring up some extra help windows. In the Indian calendar, there is sometimes a suppressed *tithi* and in order that the date be uniquely defined, the day is denoted by its civil day number preceded by a hash. The computer application should be seen as an Indian norm with which to compare the Indonesian records and discover possible structures in the intercalation schemes.

There is also a third small Java application, Pawukon Calendar, that implements the pawukon

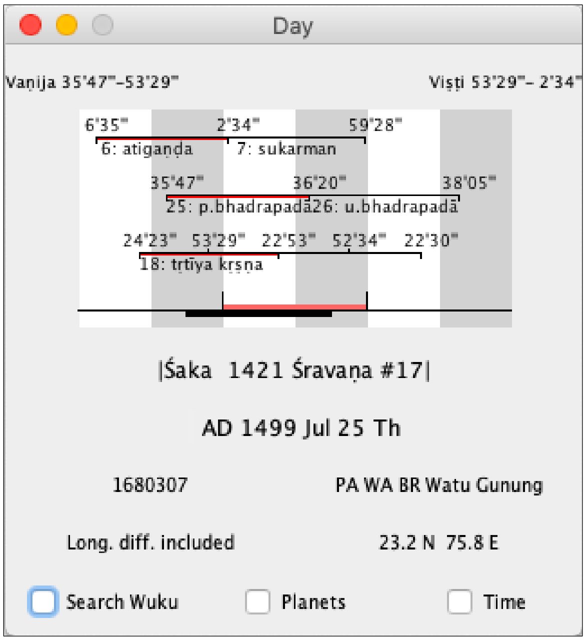



Figure 4: The HIC day window.

calendar. Any date in the Gregorian or Julian calendar can be entered (see Figure 5).

Finally, there is an application that implements the Pakkhakhanana calendar of King Rama IV (Mongkut) of Siam (see Figure 6).

These applications can be accessed freely and downloaded from the following website, http://home.thep.lu.se/~larsg/Site/SEATools.zip together with their manuals. There are versions for both the Windows and the Macintosh platforms.

The following sections show some typical calendrical records with comments. More than six hundred inscriptions and records analysed in

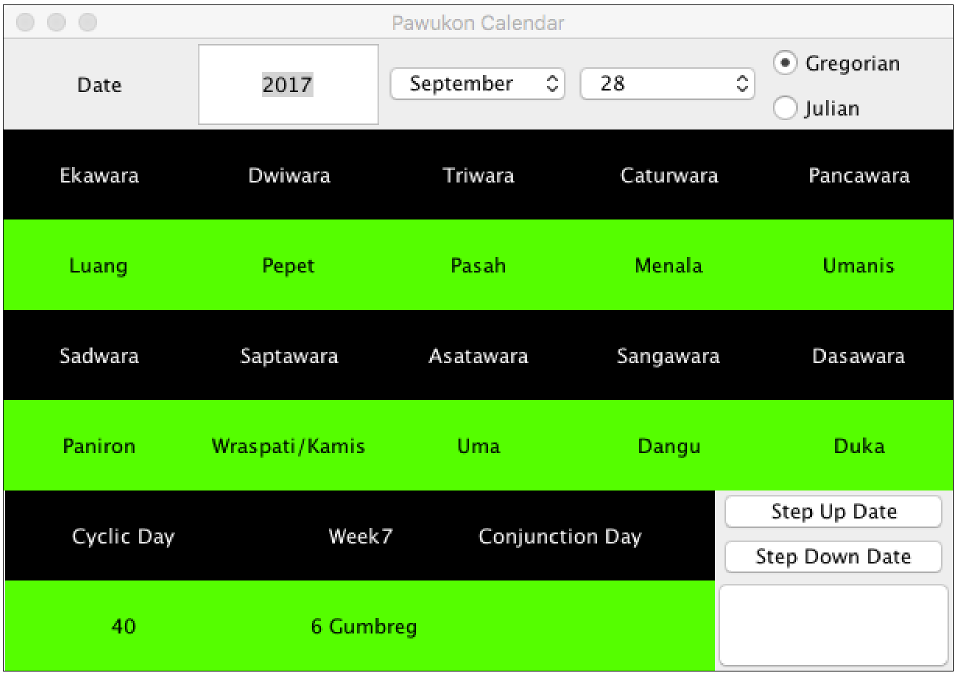



Figure 5: The Pawukon Calendar application.

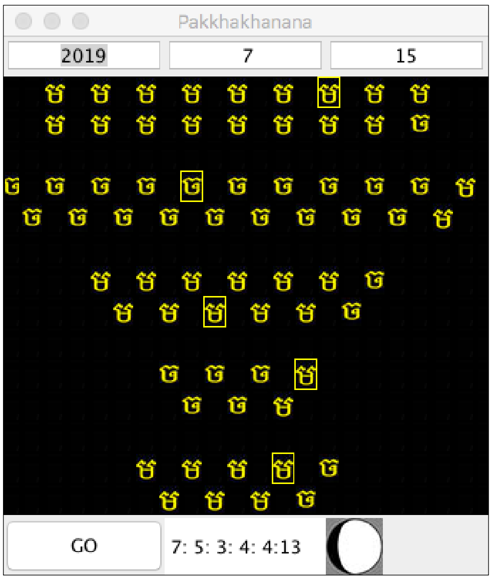



Figure 6: The Pakkhakhanana application.

detail can be found in Eade (1996) for Thailand; for Cambodia and Laos see Eade (1995); and for early Javanese inscriptions see Eade and Gislén (2000). While the selection of examples below will illustrate the typical structure of the records, we do not intend to present a deeper analysis of them here.

## 2 BURMA

The historical record of Burma has a particular distinction. As with Thailand and Cambodia there is a corpus of stone inscriptions recording political change, the founding of monasteries and the dedication of Buddha images. There is, however, another copious source of information—that provided by the many horoscopes on the walls of the temples of Pagan. This class of evidence has a title to be considered more fully in its own right. It presents many interesting problems and a wealth of data.

Predominantly they are horoscopes of individuals, and often they appear in clusters—the whole family, it seems, is represented. One has to assume that these *zata* were put in place either by persons making pilgrimage to Pagan or by locals, whose fortune in this life would be increased if their birth chart was set up in a holy place.

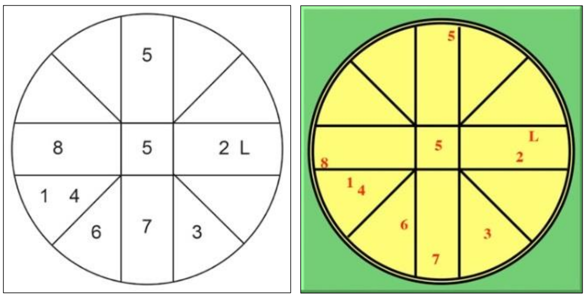



Figure 7: *Zata* from Hti-lo-min-lo (Pagan temple site 1812).

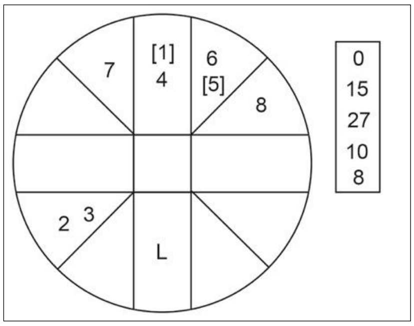
Whatever the motive and occasion, these memorials present the historian with enormously valuable information. The convention of using *zata* as a way of fortifying a historical record was also used widely in Northern Thailand, where many stone inscriptions exhibit a horoscope diagram at the apex of the stone. But in the entire Thai record there are only three instances where the horoscope is amplified by a table that also defines numerically, and hence in closer detail, the position of the planets at the moment commemorated. In the Pagan record there are dozens of such tables, and the information they present (sometimes legibly, sometimes recoverable with the exercise of a certain ingenuity) proves to be very largely correct.

One problem posed by the *zata* is where their purported age does not match their good condition. There are exceptions, such as site 1391, Kubyak-nge (Myinkaba) where some remarkably well-preserved *zata* appear nonetheless to be originals, but in some cases it seems that the *zata* have been recopied onto the walls after renovation, at a time when the originals were no longer easy to read. By contrast, the figures of these renovated *zata* do not match their purported dates. One also finds such mistakes as the appearance of a planetary numeral twice in the same diagram.

Figure 7 left shows a *zata* from Pagan temple site 1812; to the right is part of the computer output. The date is 14 Tawthalin 934 in the Burmese era = 21 August 1572. The numbers are 1 for the Sun, 2 for the Moon, 3 for Mars, 4 for Mercury, 5 for Jupiter, 6 for Venus, 7 for Saturn, and 8 for Rahu. The ordering is the same as the Western allocation of the planets to the weekdays. The position of the *lagna*, L, indicates a time of about 4 p.m. All the planets are in their correct positions. The number 5 in the middle of the *zata* gives the weekday 5 = Thursday, which is also correct.

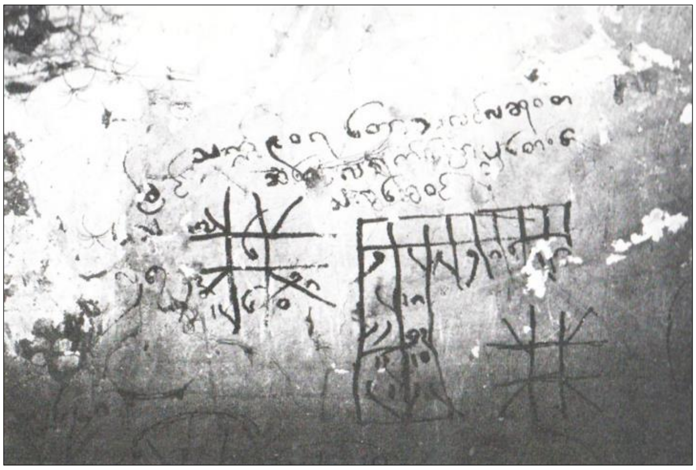
Figure 8 is a *zata* from the same place, that is partly illegible. However, it is accompanied by a table in which 0;15,27 and 10;8 can be read, the true longitude of the Sun and the *tithi*, respectively. The *tithis* can be converted into degrees 121° 36′ taking 30 *tithis* to correspond to 360°, which in turn gives the approximate longitude of the Moon as 15° 27′ + 121° 36′ = 137° 3′ = 4;17,3. It is now possible to reconstruct the date as Tuesday 23 April 1619 CE = 11 Kason 981 Burmese era. The computer output for the longitudes at midnight is shown to the right in the figure. Only Rahu (#8) is wrongly placed (in Aquarius, not in Capricorn). The *lagna* indicates a time of about 6 p.m. being opposite to the Sun.

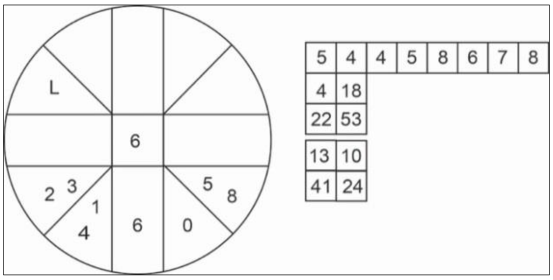
Many Burmese records (e.g. see Figure 9a–c) include a calculation of the longitudes of the planets. In this case only the longitudes of the

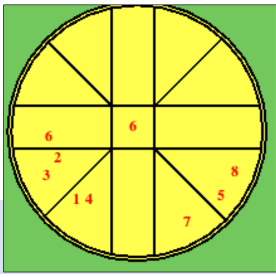



| | |
|---|---|
| 1. Sun: | 0 15 27 |
| 2. Moon: | 4 17 6 |
| 3. Mars: | 4 27 18 |
| 4. Mercury: | 0 8 43 |
| 5. Jupiter: | 11 16 13 |
| 6. Venus: | 11 2 21 |
| 7. Saturn: | 1 13 36 |
| 8. Rahu: | 9 7 44 |

Figure 8: *Zata* from Pagan temple site 1812.






| | |
|---|---|
| 1. Sun: | 5 4 21 |
| 2. Moon: | 4 18 38 |
| 3. Mars: | 4 21 25 |
| 4. Mercury: | 5 3 4 |
| 5. Jupiter: | 8 10 15 |
| 6. Venus: | 3 18 22 |
| 7. Saturn: | 7 16 1 |
| 8. Rahu: | 8 22 3 |
| Ketu | 4 10 58 |

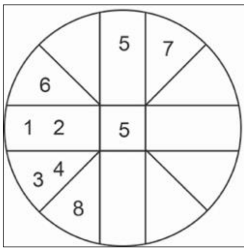
Figure 9a (above): *Zata* from Pagan temple site 2013: Mong-gu.
Figure 9b (right, top): Transliteration.
Figure 9c (right, bottom): Part of the computer output.

Sun and the Moon have been calculated completely with the *rasi*, or zodiacal sign, being given for the other planets. Venus, number 6, has *rasi* 6 in the table and in the *zata* but *rasi* 3 by the computer. Saturn, number 7, typically of many Burmese records, is denoted by 0, the reason perhaps being that in reckoning modulus seven, seven is the same as zero. The zodiacal positions of the planets except for Venus all agree with the computer output. The Burmese date is 29 (14 waning) Tawthalin 907 = 4 September 1545. The 6 in the centre answers to its being Friday, agreeing with the computer. However, the longitudes of the Sun and the Moon and the *lagna* fit a time slightly after midnight the next astronomical day, but is correct as the civil one.

Figure 10 shows a *zata* from site 1460 (just south of the city walls) that can be securely be dated to 2 Wagaung 1005 in the Burmese era = Thursday 16 July 1643. It contains a complete set of true longitudes for the planets as well as the *tithi* and *naksatra* (the two bottom numbers). The longitudes of the Moon and the Sun agree within a couple of arc minutes with the computer output. Also, the *tithi*, *nakshatra* and weekday are in place. The other planets do not agree very well. However, if the date is stepped back to 30 *Waso*, the end of the previous month, all are almost exactly reproduced.

It is a long and tedious procedure to calculate the true longitudes of the planets and obviously it was not done afresh for each horoscope but calculated for some specific dates and used for several records that were not too far away in time. As the planets, except for Mercury, move relatively slowly in longitude, the error would not be very large.

Figure 11 shows a *zata* from Wat Chiang Kham dating to 650 Kason 13 = 14 April 1288, and on the right is a transliteration. The *rasi* locations of the planets in the *zata* do not agree very well with the table but with the exception of Jupiter and Venus they do agree with the computer output. In the table and computer output Mars (3) is in *rasi* 5 but in the *zata* in *rasi* 4 and Jupiter (5) is in *rasi* 0 in the table but in *rasi* 11 in the *zata*. Only the table longitudes of the Moon and the Sun agree well with the computer, the other planets only




| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| 3 | 3 | 4 | 4 | 0 | 2 | 11 | 5 |
| 5 | 16 | 0 | 15 | 9 | 0 | 11 | 18 |
| 25 | 51 | 31 | 31 | 14 | 44 | 26 | 58 |

| | |
|---|---|
| 0 | 8 |
| 57 | 3 |

Figure 10: *Zata* at site 1460.

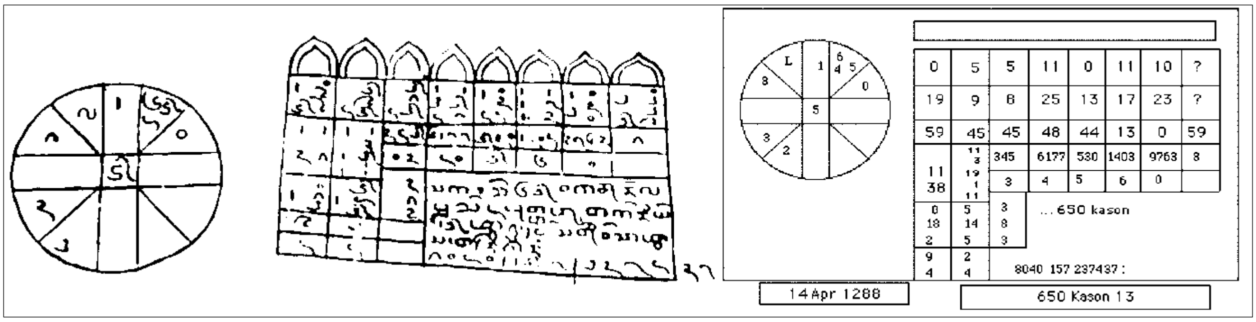



Figure 11: *Zata* from Wat Chiang Kham.

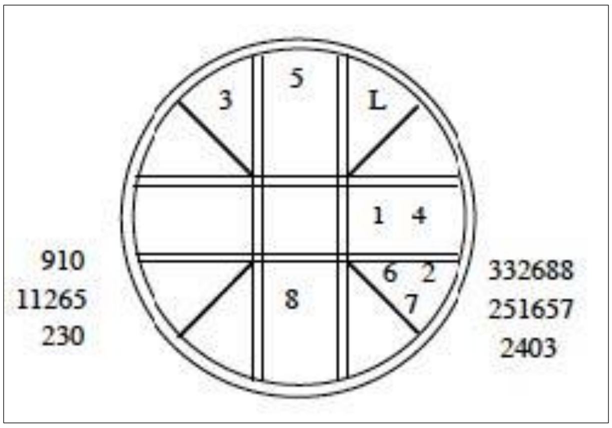



Figure 12: The Wat Chang Kam inscription (Prachum silacharuk, #74)

approximately. The *tithi* 11:38 agrees exactly with the computer output as do the mean longitudes of the Sun and the Moon, 0;18,2 and 5;14,5. Saturn as is common in Burmese records, is represented by number 0 instead of 7. The last item 0;22,59 is almost exactly opposite in the zodiac to the location of *Rahu* and could be interpreted as the location of the descending node. The precise longitudes of the Moon and the Sun are consistent with a time 0:12 after midnight on the following astronomical day, Kason 14; and the weekday 5 = Thursday in the centre of the *zata* is then correct. The line of numbers in the next to bottom line of the table is the ‗ages' of the planets i.e. their mean longitudes expressed as days of their period. The line with numbers 8040, 157, and 237437 are the *masaken*, *avoman* and *ahargaṇa*, and they agree perfectly with the computer output.

## 3 THAILAND, LAOS AND CAMBODIA

The inscription in Figure 12 is from Wat Chang Kam in Thailand, and has a layout that is common for inscriptions from Thailand. A transliteration is given to the left in the figure. The body of the inscription reads:

> Chulasakarat 910, monkey, *pœk san*, month Magha … Thai month 5, waning 12; *mœng kai*, nearly noon, the Moon was *rœek* 19; Mula, *tithi* 27.

The cyclical year agrees with the computer output but the cyclic day should be *pœk si*. The top left number by alongside the *duang* is the Chulasakarat year 910. Top right is the *ahargana*, the elapsed days from the epoch 332688. The middle left number 11265 is the *masaken*, the number of elapsed lunar months since the epoch. The middle right number is the *kammacabala*, the bottom left number 230 is the *avoman*, and the bottom right number the *uccabala* 2403. Except for the *kammacabala* all the numbers and the positions in the *duang* are exactly reproduced by the computer. However, the *kammacabala* in the inscription, 251657, is 241657 by the computer. The digits 4 and 5 in Thai look rather similar and can easily be confused. The *lagna*, positioned in Pisces, gives the time as about 9:30 a.m. The date is 27 Magha 910 = Friday 25 January 1549.

The Wat Bang Sanuk inscription, Figure 13, is located at the mouth of the brook Huai Salok, on the west bank of the Yom River, in Ampho Wang Chin, Phra Province in northern Thailand at 17° 53′ N, 99° 35′ E. It is written to commemorate gifts from ―…. the ruler of Müang Tròk Salòp and Chæ Ngun …" (Wyatt, 2001) consisting of among others Buddha images. This was an occasion accompanied by music and festivities. The inscription is very interesting and unique because it is the oldest extant example of the Thai script. It uses the sexagesimal cycle for both the day and the year and can be uniquely dated. The dating part of the inscription is marked with red in Figure 13 and is transliterated

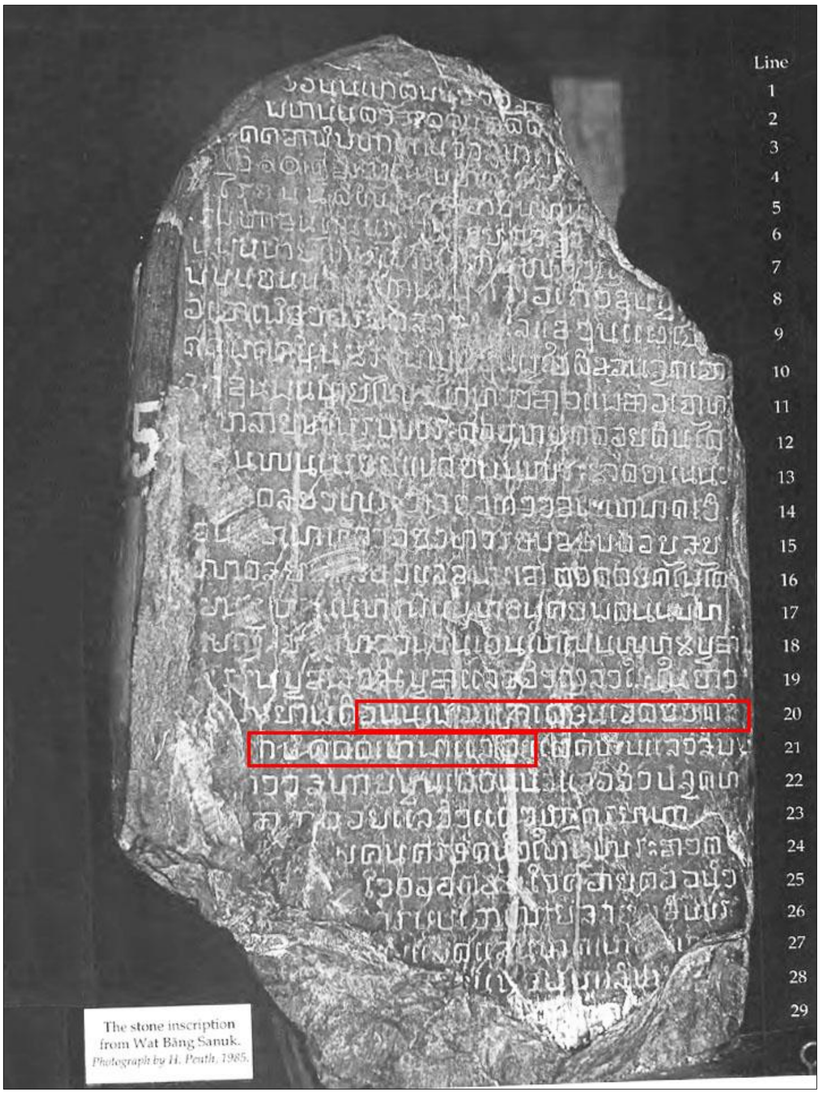



Figure 13: The Wat Bang Samuk inscription (after Wyatt, 2001).

ed into modern Thai script below:

> (20) …วนน เมิง เปลา เดิอน เจด ออก สิ… wann mœng plao düan cet òòk si
> (21) [.]ํา ปี กดด เหมา แล โถะ …[p.kh]am pī katt hmao læ …
>
> Translation: …day *mœng pao*, month seven, day 1[...] of the waxing Moon, year *kat mao* year of the hare…

An analysis (Penth, 1996) shows that the waxing day must be 11–15 and there are only two dates that fit the 60-day cycle data with an appropriate 60-year cycle. They differ in how the month number should be interpreted:

> Chulasakarat *mœng pao* 11 Caitra 581 = Thursday 28 March 1219 (Chiang Mai style).
> Chulasakarat *mœng pao* 12 Jyestha 581 = Monday 27 May 1219 (Sukhothai style).

Of these the first one is more probable, as the Thai words for the second one[3] could only fit into the space allocated on the stone with difficulty. The first date also occurs just one day after the New Year festival, which a day in Jyestha could not do. The year dating is critical because it challenges the earlier assumption that the earliest writing in Thai came from an inscription of King Ram Khamhæng of Sukhothai, dated CE 1292 and scholars have relied upon that inscription in their attempts to describe Siamese society at the end of the thirteenth century.

Figure 14 shows part of the inscription Wiang Kao at Phayao 12. The text with it reads:

> Chulasakarat 875, cock, *ka rao*, month Citta according to the astronomers, Thai month 7, waning 8, *tithi* … *rœk* called Buppasat, Meng Thursday, Thai *tao* set.

All the calendrical data in the inscription agree with the computer and all the planets except Mercury (#4) are in their correct positions. The *lagna* gives a time of about 2:30 p.m. The date is 23 Caitra 875 Chulasakarat, the solar New Year = Tuesday 29 March 1513.

> Sakarat 658, year *raway san* month Visakha waxing 8 nights, day 5. Thai day *mœng plao*, watch *trae rung* [3:00-4:30 a.m.], two *nadi* complete and two *pada*. The *lagna* is in a *nawang* of Jupiter in Mina *rasi* [Pisces].

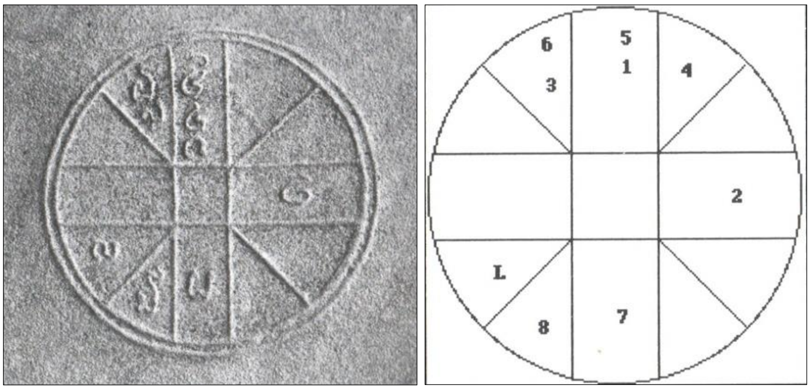
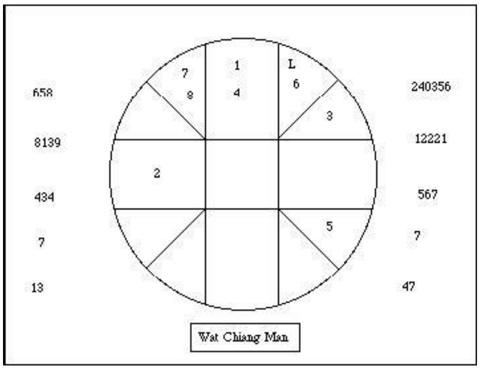



Figure 14: The Wiang Kao at Phayao 12 inscription (Prasert na Nagara, 1991: 129).



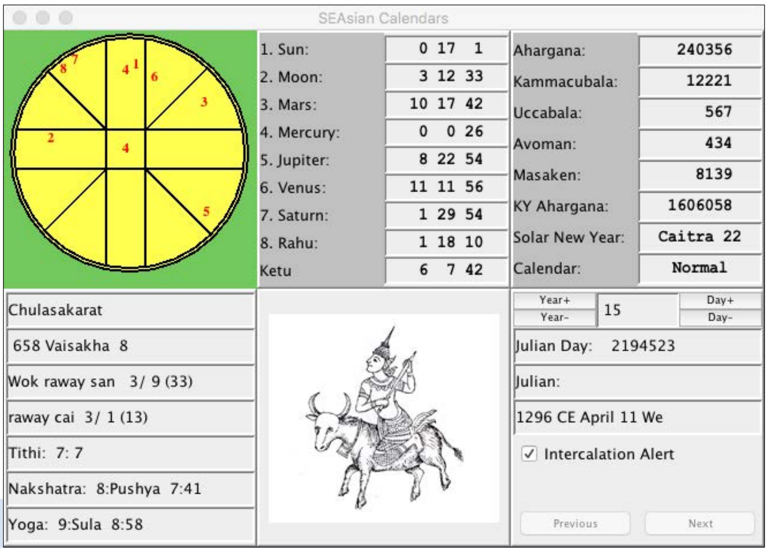




Figure 15a & b: The Wat Chang Man inscription, Chiang Mai (Prachum silacharuk #76).

The Chulasakarat date of the *duang* in Figure 15 is 8 Vaisakha 658 = Wednesday 11 April 1296. All the planets are in agreement with the computer as are the calendrical numbers. However, the *lagna*, *naksatra* and *tithi* all indicate a time of about 2:30 a.m. on the following morning. The watch given as *træ rung* is 3:00 – 4:30, which is also consistent with the cyclical day *mœng pao* of the record. This is one of the cases where the definitions of astronomical and civil day give different answers.

Some records date an event by counting the number of days since some important event in Buddha's life. These events are conventionally assumed to occur on the date of the full Moon of Vaisakha. Below are two examples that give an idea of the arithmetic involved in the reckoning.

Thai inscription 5 (Griswold, 1973: 159):

> ... on Wednesday, a ruang pao day in the Tai reckoning, in the naksatra of Punarvasu, towards evening, one thousand nine hundred and five years after our lord the Buddha entered Nirvana, [the king] was ordained. Counting by days from the Nirvana up to the day of his ordination, six hundred ninety-five thousand, six hundred and one days [695601] has elapsed.

The reckoning uses inclusive reckoning. As the year when Buddha entered Nirvana is 147 in the Achansakarat era (AS), the year of the king's ordination is 147 + 1904 = 2051 AS. The cyclical day, the weekday, and the *naksatra* determine uniquely the date as 22 Asvina 2051 AS = CE 22 September 1361. The date of Buddha entering the Nirvana is taken as 15 Vaisakha 147 AS.

By the beginning of 147 AS there had been 147·7/19 = 54 intercalary months since the epoch. By the end of 2051 AS (beginning of 2052) there had been 2052 × 7/19 = 756 intercalary months. Thus, in the years in between there were 756 – 54 = 702 intercalary months. In the interval to the end of 2051 AS were 1905 × 12 = 22860 normal lunar months, in total 22860 + 702 = 23562 lunar months.

From the beginning of the year 147 to the beginning of Vaisakha is one month and from the beginning of Asvina to the end of the year there are six months. Thus, there are 23562 – 7 = 23555 elapsed months between Vaisakha 147 and Asvina 2051. Each lunar month consists of 30 *tithis*. So, there are 23555 × 30 = 706650 *tithis* in the interval. Subtracting 14 *tithis* to reach Vaisakha 15 and adding 22 *tithis* to reach Asvina 22 we have 706650 – 14 + 22 = 706658 *tithis*. Remembering that one *tithi* corresponds

to 692/703 civil days the number of civil days is (706658 × 692)/703 = 695600 days. Using inclusive reckoning this becomes 695601 days as stated in the inscription.

The cyclic day ruang pao is number 38 in the sexagenary cycle. The cyclic change in the interval is 695600 mod 60 = 20. The cyclic day of Buddha entering Nirvana is then 38 – 20 = 18 or *ruang sai*. The change in weekday is similarly 695600 mod = 3. The Starting week day is the Wednesday which minus 3 equals Sunday. Both these items agree perfectly with the computer calculation.

Thai inscription 3 (Griswold, 1973: 94, 96):

> Sakaraja (Mahasakarat) 1279 (2047 AS), year of the cock, eighth month (Ashada), fifth day of the waxing Moon, Friday, a kat rao day in the Tai reckoning, the Moon being in the naksatra of Purvaphalguni …
>
> If anyone asks, further, ‗How long has it been from the day our lord attained Buddhahood under the srimahabodhi tree, up to the day this precious relic is being enshrined?‘, let the answer be given him: ‗Counting the years, it is one thousand nine hundred and forty-six years; the year he reached Buddhahood was a year of the monkey. Counting by months, it is twenty-four thousand and sixty months; the month he reached Buddhahood was the sixth month (Vaisakha), on the day of the full Moon (tithi 15). Counting by days, it is seven hundred and ten thousand, four hundred and sixty-eight days [710468]; the day he reached Buddhahood was Wednesday, a tao yi in the Tai reckoning.

The date of the Buddhahood was assumed to be 15 Vaisakha 102 AS = CE 23 June 1357, the date of the enshrinement using the information above be can found to be 6 Ashada 2047 AS = 23 June 1357. Repeating the calculation and assuming inclusive reckoning we have:

The number of intercalary months up to the beginning of 102 AS is 37 and the intercalary months up to the beginning of 2048 is 754. In total, there are 717 intercalary months. The number of normal months is 1946 × 12 = 23352 months, in total 23352 + 717 = 23069 months. Subtracting one month for Caitra and nine months from the beginning of Ashada to the end of the year we are left with 23059 months or with inclusive reckoning 24060 months. The number of *tithis* is (24059 × 30) – 14 + 5 = 721761 moving 14 days forward to 15 Vaisakha and 5 days forward in Ashada. Converting the *tithis* to civil days 721761 × 692/703 = 710467 days, with inclusive reckoning 710468. The day *kat rao* is number 46 in the cycle, the change in cyclic number is 710467 mod 6 = 7 and the Buddha-hood cyclic day is then number 39, *tao yi*. The weekday change is 710467 mod 7 = 2: Friday – 2 = Wednesday. All the data agree with the inscription.

However, if we check the date using the computer we find that it corresponds to 15 Jyestha 102 AS, Wednesday, *tao yi*, and not 15 Vaisakha 102, Monday *tao san* as required. What has happened is that the year 102 AS is a year with an intercalary month that has been neglected in the count in the inscription.

The Wat Phra Dhatu Chæ Hæng inscription (Prasert naNagara, 1991: 62):

> Chulasakarat 948, year of the dog, Thai rawai set, month Maghna bright fortnight three, Thai month 5 waxing 3, weekday 1, Thai ka kai, the Moon in rœk 23 called ‗tanisdata‘ (Danishta) in Mangkara (Capricorn) rasi. 2130 years past, nine months, eleven days, 2869 years to go, 2 months 19 days.

Table 1: Comparison of the inscription and the computer output.

| | Inscription | Computed |
|---|---|---|
| Sun | 9,03;09 | 9:02;57 |
| Moon | 9,28;20 | 9,28;16 |
| Mars | 5,11;42 | 5,05;36 |
| Mercury | 9,19;06 | 9,17;32 |
| Jupiter | 2,24;36 | 2,24;22 |
| Venus | 10,12;47 | 10,15;58 |
| Saturn | 0,02;21 | 0,00,59 |
| Rahu | 5,27;00 | 6,02,22 |
| Tithi | 02:05 | 02:06 |
| Naksatra | 22:22 | 22:22 |
| Yoga | 15:51 | 15:50 |

The date is 2 Magha 948 = 11 January 1587 agreeing with the cyclic day and year. The time past is normally given as the time from Vaisakha 15 but in this case from the New Year on Caitra 21, where Caitra 21 + 9 months 11 days = Magha 2. The sum of the times passed and to go is 2130 + 2869 = 4999 years, 9 + 2 = 11 months, and 11 + 19 = 30 days, equalling exactly 5000 years, as required.

The inscription in particularly interesting in that it is one of the very few Thai records that present planetary longitudes in addition to a *duang*. Table 1 shows a comparison between the inscription and the computer output for sunrise.

The differences in the true longitudes can perhaps be attributed to the complex process of converting mean positions to true positions. The *rœk* (*naksatra*) Danishta is number 23 in the *nakshatra* sequence starting with 1, 2, 3 …, but the 23$^{rd}$ *nakshatra* belongs to the interval 22–23.

## 4 AN EXAMPLE OF A DEVIATING THAI INTERCALATION

In this connection, it was useful to find in a Chinese academy report in the 1980s about the calendar used by the Dai in Southern China (Zhang and Chen, 1981), and also about the method adopted by two Northern Thai calendars-

Table 2: Deviating intercalation (years are in the Chulasakharat era).

| (Year+1) mod 19 | Year | Year Type | Year | Year Type | Year | Year Type | Year | Year Type |
|---|---|---|---|---|---|---|---|---|
| 1 | | | 1254 | A | 1273 | A* | 1292 | A |
| 2 | | | 1255 | C | 1274 | C | 1293 | C |
| 3 | [1237] | [A*] | 1256 | A | 1275 | A | 1294 | A* |
| 4 | [1238] | [B] | 1257 | B | 1276 | B* | 1295 | B* |
| 5 | | | 1258 | C | 1277 | C | 1296 | C |
| 6 | | | 1259 | A | 1278 | A | 1297 | A |
| 7 | [1241] | [B] | 1260 | A | 1279 | A* | 1298 | A* |
| 8 | | | 1261 | C | 1280 | C | 1299 | – |
| 9 | | | 1262 | B* | 1281 | B* | [1300] | [B*] |
| 10 | 1244 | C | 1263 | C | 1282 | C | | |
| 11 | 1245 | A | 1264 | A* | 1283 | A | | |
| 12 | 1246 | A | 1265 | A | 1284 | A* | | |
| 13 | 1247 | C | 1266 | C | 1285 | C | | |
| 14 | 1248 | B | 1267 | B* | 1286 | B* | [1305] | [B] |
| 15 | 1249 | A | 1268 | A* | 1287 | A | | |
| 16 | 1250 | C | 1269 | – | 1288 | C | | |
| 17 | 1251 | A | 1270 | – | 1289 | A* | | |
| 18 | 1252 | C | 1271 | – | 1290 | C | | |
| 0/19 | 1253 | B | 1272 | - | 1291 | B | [1310] | [B] |

(Watthanatham, 1985) for the thirty years on either side of CE 1900 (1262 CS)—that only years 4 9 14 and 19 in each block of 19 years received an extra day. The years adopted by the two Lanna calendars are the same years as those identified by the Chinese for the Dai calendar of southern Yunnan, indicating a substantial spread of this practical solution to the intercalation problem. This confining of the extra-day years to a schematically-based position naturally gave rise to substantial differences from their theoretically-determined place. Each year displays a layout of the months and it is possible to infer the intercalation pattern of both months and days. In the Thai manuscripts the years are accompanied by a signature number in the interval 0–18 and a Thai word เศษ, *set*, meaning ‗remainder'. It is easy to verify that the signature number is computed using the formula (year + 1) mod 19. Observing the intercalation pattern, it is obvious that some kind of cyclic intercalation has been used (see Table 2).

Table 2 is colour-coded so that A (in blue) represents normal lunar years of 354 days, B years (yellow) have an intercalary day of 355 days and C years (green) have an intercalary month of 384 days. The asterisks indicate for comparison those years where the B years are A years in the canonical reckoning or *vice versa*. Items in square brackets are interpolations, to fill in gaps in the coverage. We have changed the Lanna-Thai signature number 0 to 19. The arithmetic principle is that whereas each block of 19 years has seven C years in it, the distribution rate of B years would be eleven in fifty-seven (three blocks of nineteen). The Table indicates that as between the canonical scheme and the practice in Lanna and Yunnan there was disagreement about where the extra day should fall in six of the eleven cases from CS 1254 on—though of course by the end of the fifty-seven-year period the same total number of days had passed.

All the years with remainders of 2, 5, 8, 10, 13, 16 and 18 have been assigned an intercalary month, agreeing with the canonical scheme. Actually, it is possible to use such a quasi-Metonic intercalation also in the canonical scheme given that the intercalation sequence is changed now and then, presumably by directive from higher authorities.

Using such a fixed insertion scheme both for intercalary years and days would be a quite substantial simplification of the complicated original intercalation rules, and would save a lot of work for the calendarist. Some other intercalation deviations have been analysed by Eade (2007).

## 5 INDONESIA

The early Javanese horoscope records use the *pañcanga* system with several extra pieces of information being given, such that the record contains quite a lot of redundant information, useful as an aid to dating. The five *pañcanga* elements are:

(1) The *tithi*. The Moon's separation from the Sun. It is counted waxing (*śuklapakṣa*) from 1 to 15 and then waning (*kṛṣṇapakṣa*) 1 to 15 or 14. *Purnami*, the Full Moon day, is *tithi* 15 waxing. In the Javanese records the *tithi* is almost always synonymous with the number of the civil day in the month.
(2) The weekday. In most cases given as abbreviations for the 6-, 5- , and 7-day weekdays, and often with the added name of the *wuku's* seven-day week name.
(3) The *naksatra*. This is the Moon's position in longitude, given as the position in the zodiac divided into 27 parts.
(4) The *yoga*. The sum of the longitudes of the Sun and the Moon, given as the position in the zodiac divided into 30 parts.
(5) The *karaṇa*. Each *tithi* is divided into two

*karana*.

Inscription A23 (Eade and Gislén, 2000: 16) exhibits these five elements in order, interspersed with other technical elements whose principle of organisation has not yet been deciphered.

Year: 782; month: Kārtikka
*Tīthi:* 13 waxing
Day: ma (Maulu) pa (Paing) wṛ (Wraspati);
Week: Landep (#2)
*Nakṣatra:* Aśvīṇa (#1)
*Yoga:* Vyātipāti (#17)
*Karaṇa:* Taithila

The terms given here in brackets are the ‗jyotisa elements'; since it has not been possible to classify them systematically we will ignore them.

The partial computer output for the first of these records is shown in Figure 16, computed for the latitude 7.5° S and longitude 110° E of central Java. The top line shows the *yoga*, the next line the *naksatra*, and the next line the *tithi*. The red bottom line shows the extent of the civil day, sunrise to sunrise, the black line shows the extent of the astronomical day, midnight to midnight. In this case the *tithi* and the number of the civil day in the month coincide. All five *pañcanga* elements in the text are replicated by the computer program for the morning of CE 31 October 860.

The same close agreement is also manifest in inscription A151 (Eade and Gislén, 2000: 84):

Year: 1057; month: bhadrawāda (bhādrapadra)
*Tithi:* trayodaśi kṛṣṇapaksa (28)
Day: wu pa sa
Week: Wukir
*Nakṣatra:* māghā
*Yoga:* śubha
*Karana:* waṇija

This is the example shown in Figure 17 where the civil calendrical date of day 27 differs from the astronomical *tithi* 13 waning (28), and the astronomical *tithi* is used in the inscription. The hour is some time after sunset.

In the third example, inscription A61 (Eade and Gislén, 2000: 23; cf. Damais, 1945–1958), the relation is reversed, where it is civil 13 waxing on astronomical day 12 waxing, against the Indian ‗rule' that the day's number was determined by the *tithi* in force at sunrise:

Year: 808; month: phālguna
*Tithi:* trayodaśi śuklapaksa (13)
Day: wurukung (wu) kaliwuan (ka)
bṛhaspatiwāra (br)
*Nakṣatra:* pusya
*Yoga:* śobhaṇa
*Karana:* —

Figure 18 shows this example where the calendrical day 13 is used but the astronomical *tithi*

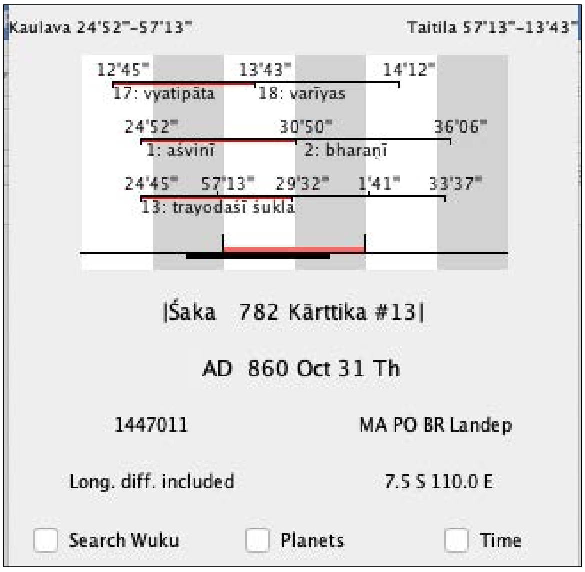



Figure 16: Computer calculation of the Javanese record.

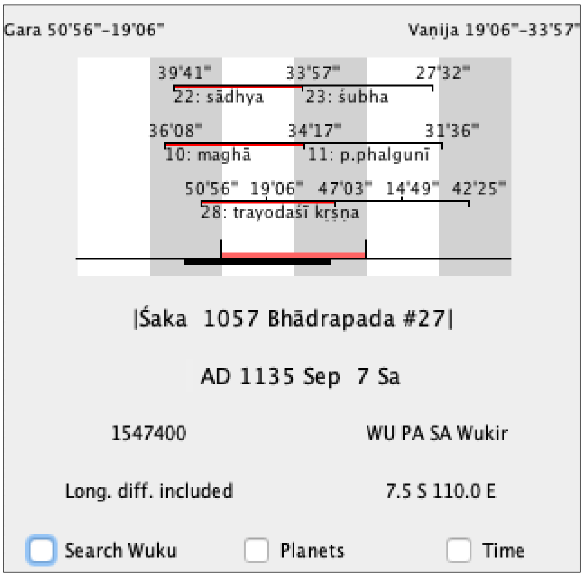



Figure 17: Computer calculation for inscription A151.

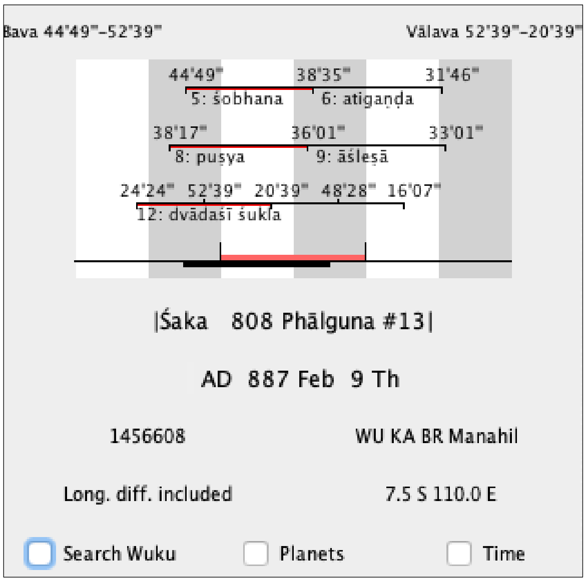



Figure 18: Computer calculation for inscription A61.

is 12 (*dvadasi sukla*). All the *pañcanga* elements are in place except the *karaṇa*, which is missing.

Figure 19 shows a month in a modern Balinese calendar. There are several calendars on simultaneous display. At the top is the Śaka year 1937, which equates in the Gregorian calendar with February 2016. The large numbers show the dates in this calendar. Each day also displays the pawukon weekdays, in this case, 8 February, the 1-day weekday is Luang, the 2-day weekday is Pepet, the 3-day weekday is Kajeng, the 4-day weekday Jaya, the 5-day weekday Pon, the 6-day weekday Maulu, the 8-day week-day Kala, the 9-day weekday Erangan, and the 10-day weekday Pati. The 7-day weekday Coma/Soma appears in the column to the left, together with the ordinary weekday name Senin. Kasanga is the name of a solar month here used for a lunar month, the red typeface of the Kasanga and the number 1 indicating that it is the first day of the waxing Moon. Top left are the calendar month and days of the Islamic (Javanese and arithmetic Muslim) calendars. Dungulan at the top of the column is the eleventh wuku week in the 210-day cycle.

## 7 CONCLUDING REMARKS

The combined picture of the calendrical records confirms the existence of a long and continuous tradition of rules for computation going back hundreds of years or even millennia. Although all the countries in Southeast Asia now officially use the Gregorian calendar, the traditional luni-solar calendars are still an extremely important part of religion and culture in the societies.

## 6 NOTES

1. This is the sixth and final paper in the series that discusses the traditional calendars of Southeast Asia. The first paper (Gislén and Eade, 2019a) provided an introduction to the series. Paper #2 (Gislén and Eade, 2019b) dealt with the calendars of Burma, Thailand, Laos and Cambodia; Paper #3 (Lân, 2019) with Vietnam; and Paper #4 (Gislén and Eade, 2019c) with Malaysia and Indonesia. Paper #5 Gislén and Eade, 2019d) mainly discussed Southeast Asian eclipse calculations.
2. Specialist terms used in this paper are listed in the Glossary, in Section 9.1 below.
3. In Thai eleven is สิบเอ็ด, *sip et*, while twelve is สิบสอง, *sip song*.

## 8 REFERENCES


Damais, L.-C. 1945–1958. Etudes d'épigraphie Indonésienne. *Bulletin de l'Ecole Française d'Extrême Orient*, 45–47, 49

Eade, J.C., 1995. *The Calendrical Systems of Mainland South-East Asia*. Leiden, Brill.

Eade, J.C., 1996. *The Thai Historical Record – A Computer Analysis*. Tokyo, The Centre for East Asian Studies for UNESCO.

Eade, J.C., and Gislén, L., 2000. *Early Javanese Inscriptions. A New Dating Method*. Leiden, Brill.

Eade, J.C., 2007. Irregular dating in Lan Na: an anomaly resolved. *Journal of the Siam Society*, 95, 111–122.

Faraut, F.G., 1910. *Astronomie Cambodgienne*. Saigon, F.H. Schneider (in French).

Gislén, L., and Eade, J.C., 2019a. The calendars of Southeast Asia. 1: Introduction. *Journal of Astronomical History and Heritage*, 22, 407–416.

Gislén, L., and Eade, J.C., 2019b. The calendars of


Figure 19: Example of a modern Balinese calendar (Gislén Collection).

Southeast Asia. 2: Burma, Thailand, Laos and Cambodia. *Journal of Astronomical History and Her-Heritage*, 22, 417–430.

Gislén, L., and Eade, J.C., 2019c. The calendars of Southeast Asia. 4: Malaysia and Indonesia. *Journal of Astronomical History and Heritage*, 22, 447–457.

Gislén, L., and Eade, J.C., 2019d. The calendars of Southeast Asia. 5: Eclipse calculations, and the longitudes of the Sun, Moon and planets in Burmese and Thai astronomy. *Journal of Astronomical History and Heritage*, 22, 458–478.

Griswold, A.B., and Prasert na Nagara, 1973. The epigraphy of Mahādharmarājā I of Sukhodaya. Epigraphal and historical studies No. 11 Part 1. *Journal of the Siam Society*, 61, 71–179.

Lân, T.L., 2019. The calendars of Southeast Asia. 3: Vietnam. *Journal of Astronomical History and Heritage*, 22, 431–446.

Penth, H., 1996. The date of the Wat Bāng Sanuk inscription. *Journal of the Siam Society*, 84(2), 5–26.

*Prachum Silacharuk*, *Seven Volumes*. Bangkok, Fine Arts Department (1924–1993).

Prasert na Nagara, 1991. *Lanna Inscriptions*. *Part I, Two Volumes*. Bangkok.

Watthanatham et al., 1985. Tamnān Phraya Indra, Patithin 100 pī Lānnā Thai (in Thai).

Wyatt, D.K., 2001. Relics, oaths and politics in thirteen-century Siam. *Journal of Southeast Asian Studies*, 32, 3–66.

Zhang, G., and Chen, J., 1981. Research on calendars of the Dai. In *Collected Articles on the History of Chinese Astronomy*. *Volume 2*. Beijing, Kexue chubanshe. Pp. 174–282 (in Chinese).

## 9 APPENDIX

### 9.1 Glossary

*adhikamasa* An indication as to whether or not a given year has an intercalary lunar month in it.

*adhikawan* An indication as to whether or not a given year has an intercalary day in it.

*ahargaṇa* The number of elapsed days since the epoch.

*avoman* The excess of lunar days over solar days in units of 1/692 of a lunar day modulus 692.

*duang* A graphical representation of the zodiac with the location of the planets.

*kammacabala* A quantity that gives the excess of solar days over whole solar days.

Ketu An artificial celestial body in Southeast Asian astronomy moving with ten times the speed of Rahu.

*lagna* An Indian term for the ascending zodiacal sign and used to give the time of the day.

*masaken* The number of elapsed lunar months since the epoch.

*nakṣatra* A measure of the Moon's longitude where the zodiac is divided into 27 parts, each of which covers 13° 20′.

*pañcanga* A set of five calendrical items attached to a calendrical day and used in Javanese records.

Rahu The entity known in the West as the "Dragon's Head". In Southeast Asian astronomy considered to be a separate planet.

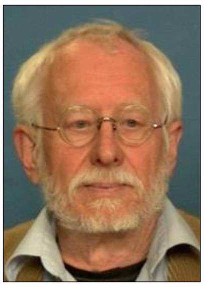
*tithi* It can refer to the lunar day number in a month and also the relative position of the Moon relative to the Sun.

*uccabala* A measure of the position of the Moon's apogee. It increases by one unit a day to a maximum of 3232.

*wuku calendar* Indonesian cyclic calendar based on a combination of 6-, 5- and 7-day weeks (in that order).

*yoga* An artificial quantity being the sum of the longitudes of the Sun and the Moon. It is expressed as the possible 360° divided into 27 parts, each spanning 13° 20′.

*zata* See *duang*.



**Dr Lars Gislén** is a former lector in the Department of Theoretical Physics at the University of Lund, Sweden, and retired in 2003. In 1970 and 1971 he studied for a Ph.D. in the Faculté des Sciences, at Orsay, France. He has been doing research in elementary particle physics, complex systems and applications of physics in biology and with atmospheric physics. During the past twenty years he has developed several computer programs and Excel spreadsheets implementing calendars and medieval astronomical models from Europe, India and Southeast Asia (see http://home.thep.lu.se/~larsg/).

**Dr Chris Eade** has an M.A. from St Andrews and a Ph.D. from the Australian National University. In 1986 he retired from the Australian National University, where he had been a Research Officer in the Humanities Research Centre before moving to an affiliation with the Asian Studies Faculty, in order to pursue his interest in Southeast Asian calendrical systems. In particular, research that he continued after retirement concerned dating in Thai inscriptional records, in the horoscope records of the temples of Pagan and in the published records of Cambodia and Campa.